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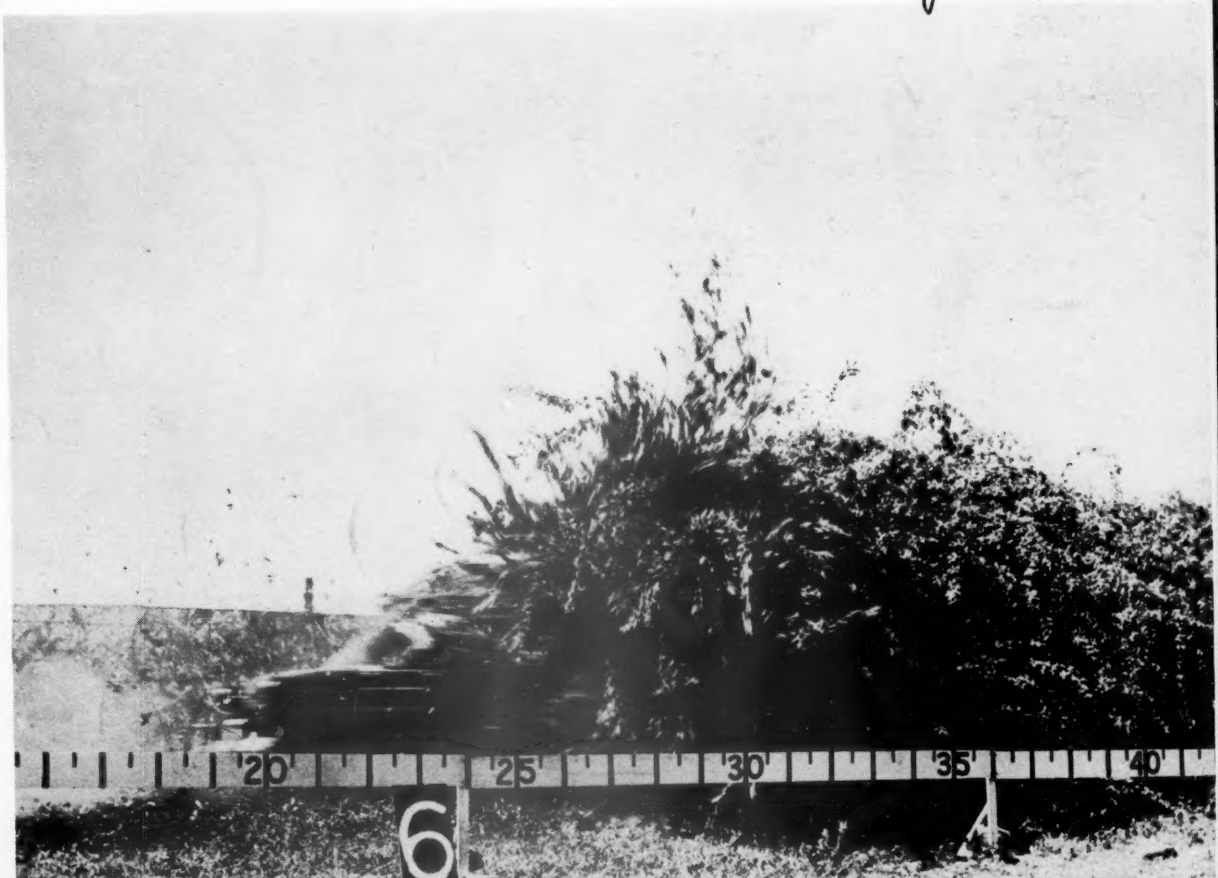

Testing the effectiveness of multiflora rose hedges as a crash barrier.

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Crash-Barrier Tests on Multiflora Rose Hedges

By RUSSELL R. SKELTON,[1]
Professor of Civil Engineering,
University of New Hampshire

A number of colorful stories have appeared in print during the past few years about the possible use of multiflora rose hedge as a safe crash barrier in the median of a divided highway. They have sprung to some extent from the limited tests described in this article. The facts show that a multiflora rose hedge can safely stop an automobile, moving at 50 miles an hour, in a distance of about 75 feet on the path of travel. At an approach angle of 20 degrees, under such circumstances, a hedge 40 feet wide would be needed to stop the vehicle. However, even on the Interstate System, medians will usually provide less than this required distance—and vehicles quite commonly will be traveling more than 50 miles an hour.

The author presents in this article only the conclusions that may properly be drawn from this test of a multiflora rose hedge as a crash barrier. Other considerations indicate that plantings in medians as crash barriers are likely to be fully and economically useful only under special conditions. Economic factors involved in the use of crash-barrier median hedges were not studied in this test, but they are important. The initial planting cost and the cost of pruning and replacement may not be insignificant. Hedges, particularly of the thorny multiflora rose, accumulate a great deal of trash, paper, and other litter, which may be more expensive to remove than on a grassy median. Medians are often used, in the Northern States, for storage of snow plowed off the pavement, and the hedges may necessitate a different snow-removal practice.

One of the cited merits of median plantings is the elimination of headlight glare from traffic on opposing roadways. There seems little doubt as to the validity of this point. However, other highway-user reactions need to be considered. The hedges will cut off headlight glare, but they will also cut off the view of the opposing roadway and the scenery beyond it. Plantings will be attractive in summer, but less so in winter. The monotonous "tunnel" effect of continuous plantings may affect driver behavior.

All of these possible advantages and disadvantages should be weighed. Several States now have experimental plantings, and their performance, costs, and effects should be carefully studied.

PLANNED LANDSCAPING, using shrubs, not only could make a highway more attractive and less monotonous but these same shrubs could save lives. Judicious planting of several varieties of shrubs in median strips would not only reduce headlight glare but the same shrubs could act as a barrier or buffer between opposing streams of traffic. Also, such plantings could prevent disastrous impacts into bridge abutments or center piers.

Considering the recent trend in highway fatalities and injuries, every idea, every device, and every plan that offers any possible chance of saving lives should be critically studied. For that reason the Bureau of Public Roads and the University of New Hampshire became interested in the idea that a barrier of shrubs could serve as a living guard rail. The university, in 1954, proposed a program for testing the effectiveness of multiflora rose hedges as crash barriers, and the Bureau approved a sponsored research grant for the study.

The firm of Motor Vehicle Research, Inc., of South Lee, N. H., was retained as a consultant in the operation of the project. The firm's director, Andrew J. White, had previously run several crash tests on multiflora rose hedges. His earlier experiences were largely responsible for the Bureau's and university's interest in conducting a larger and more comprehensive testing program to determine the effectiveness of multiflora rose hedges as highway crash barriers under the impact of an automobile.

Of immediate and specific interest in the test program were: (1) the distance required to stop the vehicle after striking the hedge at various speeds and angles of approach, (2) the magnitude of deceleration, (3) the performance characteristics of the hedge and vehicle, (4) the extent and character of damage to the vehicle and hedge, and (5) a comparison of the stopping distance and hedge performance for the summer and winter tests.

A continuous single row of multiflora rose hedge, 14 years old and averaging 9 feet high and 10 feet wide, was used for the crash tests. A schedule of 11 field tests per season was planned, to include 5 angles of approach ranging from 5° to 90° (head-on) and from 1 to 3 speeds between 30 and 50 miles per hour for each angle of approach. The proposed schedule of tests had to be drastically reduced because the length of hedge destroyed by each run was considerably greater than was initially expected. Nine tests were run in July and three were run in December of 1955

Consideration of Findings

The following findings are based upon the results of tests obtained under the conditions described later in the report:

1. The effective travel length within the multiflora rose hedge required to stop a passenger car for a given speed, without the use of power or brakes, was dependent upon the age of the hedge bushes, their density, and their spacing.
2. The multiflora rose hedge proved to be an effective barrier for stopping a passenger car, provided the width was sufficient to prevent the vehicle from passing through the hedge. For the vehicle to be stopped within the hedge at a speed of 50 miles per hour, without the use of brakes or power, the minimum required effective length of hedge on the path of travel was 75 feet.
3. Angular approach and contact with the hedge did not deflect the car away from the barrier. Once the car was turned into the hedge, the angle-approach crash appeared to require about the same effective length of hedge to stop the car as was required by the head-on crashes.
4. The hedge provided a tough, resilient yielding barrier and permitted the forces of impact to be absorbed so gradually that the maximum deceleration was well within human tolerance.
5. The performance and effectiveness of the hedge in stopping the car were about the same for the winter tests as for the summer tests.
6. It was estimated that 25 percent of the bushes were pulled out in a crash. The remaining 75 percent were not critically damaged and probably will grow again to almost full effectiveness within a few years.
7. The test vehicle was not damaged except for very minor scratches.
8. During the destructive testing, a recurring phenomenon indicated that a sizable portion of the crash energy was absorbed after a mass of loose sheared bushes had accumulated ahead of the car. The shearing of the bushes ceased

[1] This article was presented at the 36th Annual Meeting of the Highway Research Board, Washington, D. C., January 1957.

Figure 1.—Typical section of multiflora rose hedge and parallel road.

when the moving mass bent over the forward bushes.

9. Conclusions drawn from the test driver's observations and reactions are summarized as follows: (a) After the car crashed the barrier and was enmeshed in the hedge, the driver had no steering control of the vehicle; (b) the forces experienced during the stopping period seemed no more severe than an extreme emergency stop.

On the basis of the test data, it is estimated that the total width of hedge required for stopping passenger cars within the hedge, when traveling at speeds not exceeding 50 miles per hour and without brakes or applied power, would be about as follows:

Angle of approach, degrees	*Width of hedge, feet*
5	25
10	30
20	40
30	50
90 (head-on)	80

Divided highway medians should have about 10 feet clear space adjacent to each roadway pavement as emergency shoulders. Total median width, if plantings are used as crash barriers, would thus have to be about 20 feet wider than the hedge widths recommended. It might be pointed out that the optimum minimum recommended median width for the Interstate System, in flat and rolling topography in rural areas, is 36 feet.

A hedge insufficiently wide to prevent a complete breakthrough would nevertheless slow the crashing vehicle considerably. Such an advantage, however, might largely be nullified by the "surprise" effect on motorists in the opposing roadway, who would have practically no advance warning that a vehicle was crossing the median.

Characteristics of Rosa Multiflora

This plant was first described by Thunberg, a Swedish botanist, in 1784. The plant is of Asiatic origin and many varieties were found in Japan, Korea, and along the China coast. The plant was first introduced to Europe and America about 1875.

Rosa Multiflora (japonica) is described as "a vigorous, dense shrub with long, arching, moderately thorny canes often exceeding 12 feet in height and width, and producing enormous quantities of single, white, blossoms in many-flowered pyramidal corymbs, in late May or early June . . . . Test plantings have proved that *R. multiflora* is adapted to all but extreme northern and southern states, and that when planted at one-foot intervals in a soil of average fertility, either alkaline or acid, will grow into an effective barrier against all livestock, except poultry, within three to six years." [2]

The multiflora plant, as tested, appeared to have a rather shallow but somewhat massive root system. The root system was confined to an area smaller than the total spread of the canes from one plant. Several of the roots encountered were as large as the largest cane and measured 6 feet in length. The root system seemed to provide very firm anchorage.

The plant does not produce suckers, hence a hedge may be controlled by pruning; however, birds carry the seeds, and seedling plants frequently spread rapidly on adjacent land. A hedge of the plants, when planted on 3-foot centers, will form an impenetrable barrier within 8 years. The canes branch and spread laterally, intertwining to form a dense barrier which is shock resistant.[3] It is this springlike characteristic that makes the Rosa Multiflora a potentially ideal plant for use along our highways as a living guard fence.

The Test Site

The continuous single row of mature multiflora rose hedge used for the tests was located in the vicinity of Manchester, Conn. The hedge was 14 years old, and was donated to the university by the owner for test purposes. The average height was 9 feet and the average width was 10 feet. The density of growth varied considerably in different sections, as did the individual cane diameters. The plants were spaced about 3 feet apart and there were few instances of seedling plants developing within the existing hedge.

A narrow earth road ran parallel with the hedge for its entire length. This road was used for the approach run for all tests. Figure 1 shows one section of the multiflora rose hedge and the adjacent road. The section shown contained 310 feet of hedge which was used for crash testing at various angles of approach. The extreme end was used for one high-speed winter test.

Test Car and Instrumentation

The test car, a 1952 Ford, 6-cylinder, 4-door sedan, was loaned to the university by the Bureau for the duration of the two-season field test period. It was stripped of all nonessential interior equipment that could possibly contribute to the injury of an occupant. The seats were removed and two front

Figure 2.—Test car being equipped with plastic foam for driver protection.

[2] *History of the Rose,* by Roy E. Shepherd. The Macmillan Co., New York, 1954, pp. 32-39.

[3] See footnote 2; also *The Multiflora Rose for Fences and Wildlife,* by Wallace L. Anderson and Frank C. Edminister. Leaflet No. 374, U. S. Department of Agriculture, Washington, D. C., Dec. 1954.

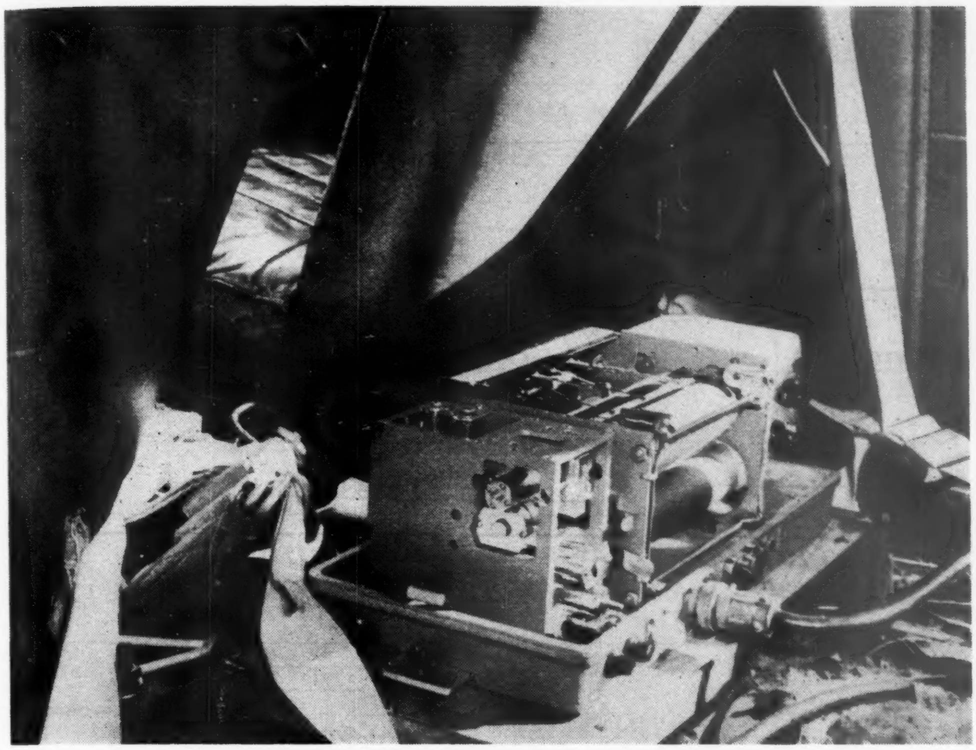

Figure 3.—Mounting of accelerometer in test car.

bucket-type seats were bolted to the floor. Two sets of 4-inch-wide seat belts and two sets of shoulder harness were fastened securely to the floor of the car. The dash assembly was fitted with a 6-inch covering of polystyrene plastic foam. Figure 2 shows the protective plastic foam being fitted to the interior.

A tachograph mounted on the firewall under the hood was coupled to the speedometer adapter gear. This instrument was used to obtain the top speed of the car during the approach run. The test car speedometer was calibrated by attaching a previously calibrated test wheel to the rear bumper and recording simultaneous readings at 10-miles-per-hour intervals up to 60 m.p.h. The test car speedometer readings were generally 6 to 10 percent higher than the true speed.

Since one of the principal objectives of the study was to determine the magnitude of deceleration, a motor-driven, constant-speed, three-component accelerometer was obtained for these tests. This instrument is shown in place with the cover removed in figure 3. The accelerometer weighed 18 pounds and measured 8 inches wide, 8 inches high, and 18 inches long.

The accelerometer was positioned on the centerline of the car and as near the actual center of gravity of the car as the front seats would permit. Actually the center of the instrument was 13⅞ inches to the rear of the center of gravity of the loaded car. In the vertical direction the center of the instrument was very close to the center of gravity of the car.

The accelerometer was equipped with a 115-volt, a. c., 60-cycle, electric motor and inverter. The 6-volt car battery was used as a source of power and heat for the styli and the case. Remote control switches were furnished for the operation and control of the motor and heaters. Wax-coated charts, 7 inches wide, having a 2-inch space for each component were used for recording the acceleration and deceleration over the full range of each stylus. The chart speed was 60 inches per minute.

The maximum deceleration in terms of gravity (g) for each direction was estimated and the manufacturer set each stylus to the specified range as follows: longitudinal direction, plus and minus 10 g; vertical direction, plus and minus 5 g; and lateral direction, plus and minus 5 g. The natural frequency was certified to be 15 cycles per second. Orifices were provided for air damping in all three planes. The degree of damping recommended and used on these tests was 80 percent, and the manufacturer calibrated and certified the instrument.

A single component recording, spring-driven accelerometer was placed in the spare tire well in the rear of the car. This instrument was positioned to record the acceleration in the vertical direction. The range of this instrument was plus or minus 1 g.

The test car hood and front fenders were given a heavy coat of white water-soluble paint prior to field testing so that the car could be more easily followed in the photographs. This covering also served to mark the points of severe contact with the bushes. Distinctive reference marks were placed on the vehicle to aid in the analysis of photographic film.

Photographic instrumentation included one spring-driven, 35-mm., wide-angle-lens camera set to run at a speed of 48 frames per second, and one power-operated 16-mm. camera set to run at 128 frames per second. The cameras were positioned perpendicular to the axis of the hedge on an elevated platform at a measured distance from a reference fence. They were adjusted to include the entire crash performance and a portion of the approach run. One additional spring-driven 16-mm. camera, operating at 64 frames per second, was used to obtain the general performance characteristics of the hedge and car.

A reference fence was erected parallel to the axis of the bushes for each test. This fence served as a base line for measurement and a photographic reference for film analysis. This reference fence is shown in the cover picture.

Test Procedure

Since the hedge consisted of a continuous single row of intertwined bushes, the tests were limited to head-on and small-angle crash tests. Because of physical limitations of the access road and the small width of the hedge, angles of approaches greater than 20 degrees were not made. In head-on tests, the car approached and crashed along the axis of the hedge at an established point. In angle tests, the car approached on a line marking an established angle with the hedge centerline and crashed the fringe of the hedge at a fixed point.

Before running a test, the point of contact, the centerline of the hedge, and dimensions of the hedge were measured in relation to the reference fence. When feasible, a bush count and the number and diameter of individual canes for several typical bushes were made. Representative cuttings were taken for water content determination. All tests were made on sections of the hedge unaffected by previous tests.

In general, the driver declutched the car approximately 20 feet ahead of the marked contact point. This standard procedure eliminated applied power, leaving only the momentum of the car to be considered in the analysis. The loss of speed in this short distance was usually of the order of 8 m.p.h. The roughness and lack of compaction of the approach road not only reduced the speed but introduced considerable pitching of the car in a vertical plane. The latter condition was more pronounced on low-speed tests.

The accelerometers were turned on when the test car started the approach run. All cameras were started when the car was about midway of the approach. Immediately after the car had stopped, the distance from the front bumper to the contact point was measured and recorded as the stopping distance. Offset distances from the reference fence to the tire tracks were made for record. A sketch was prepared showing the area and number of bushes damaged and the final position of the car in relation to the hedge and reference fence. Figure 4 is a sketch of a typical head-on crash and figure 5 is one of a 5° angle test. Also, following each test, the driver's observations concerning the test were noted. The test car was then removed from the hedge and examined.

Film Evaluation

All films were developed and reduced to 16-mm. positive prints for evaluation by a frame-by-frame method of analysis. A microfilm viewer having a large screen was used for the 48- and the 64-frames-per-second (fps) film analysis. The 128-fps film was analyzed

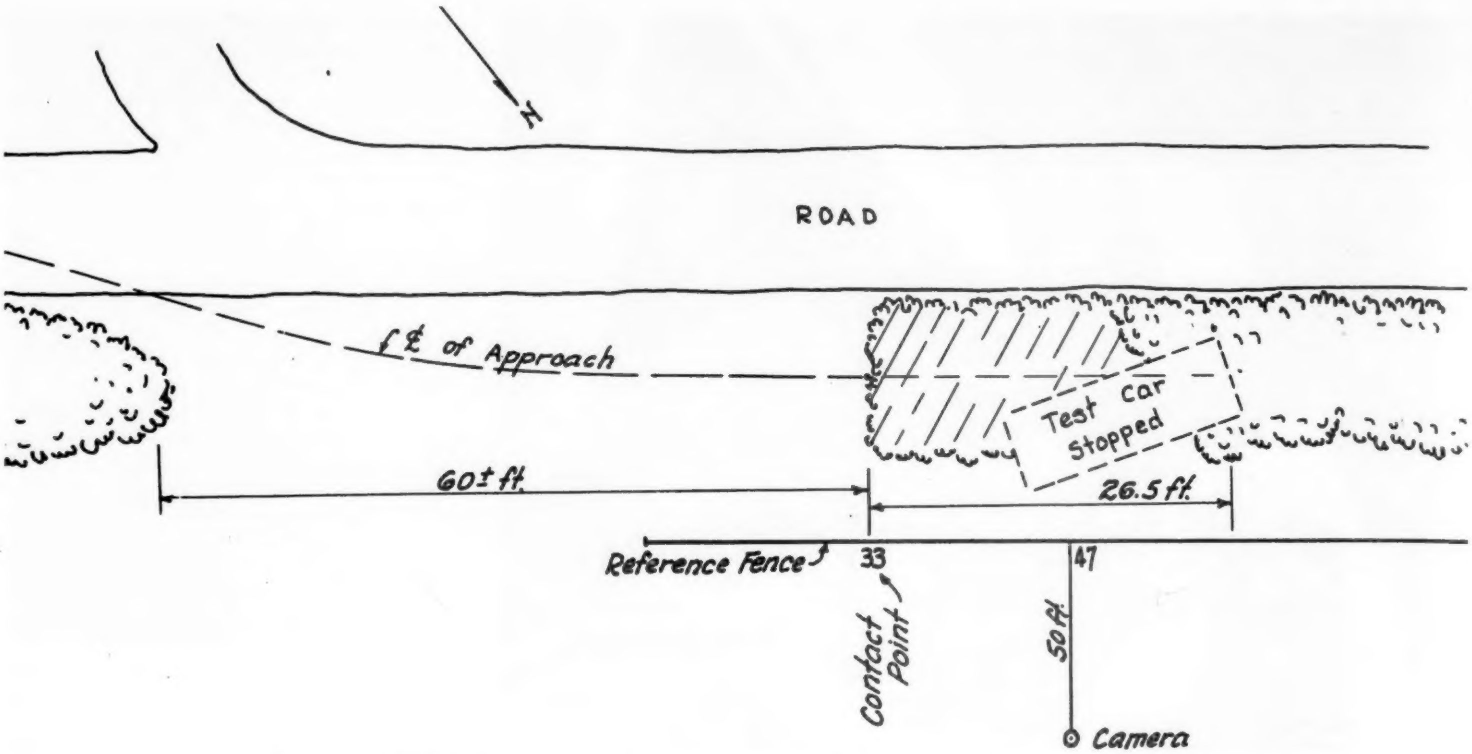

Figure 4.—Sketch of test No. 1 (head-on approach at 30.3 miles per hour contact speed).

by using a time-study projector. A sufficient number of check tests were made on several films using both pieces of equipment to determine whether the results obtained were in satisfactory agreement.

In the frame-by-frame analysis, the film was run until the test car came into view at a point in line with the reference fence. One of the several reference points on the car was selected and noted. The initial frame was recorded as zero and the reading of the footmark on the fence immediately below the reference mark was observed and recorded. The film was then advanced one frame and the process repeated, using the same car reference point. If the car advanced to a point where the first reference mark was obscured by the bushes, another car reference mark was selected and this frame was recorded as zero. The process continued until the car stopped.

Since the horizontal perpendicular distance from the camera to the reference fence and the distance from the reference fence to the car's tracks were known, the actual distance the car traveled in relation to that shown by the film was computed by a simple proportion. This corrected distance traveled per frame was then converted to miles per hour. Finally, all distances and time were equated to the front bumper of the test car and the data were used to plot speed-distance and speed-time curves for each test run.

For example, the speed-distance curve for test No. 1 is shown in figure 6, and the speed-time curve for the same test is shown in figure 7. Distances shown in figure 6 are the actual distances on the traveled path of the test car. In figure 7 the abscissa indicates the observed frame numbers, where one frame equals one forty-eighth of a second. Each plotted point is an average of five observations. All observations are in reference to the front bumper of the test car.

It is seen in figures 6 and 7 that the test car approached the contact point at 30.3 miles per hour. The film evaluation was the primary means used for determining the contact speed. From a study of the two curves, it is

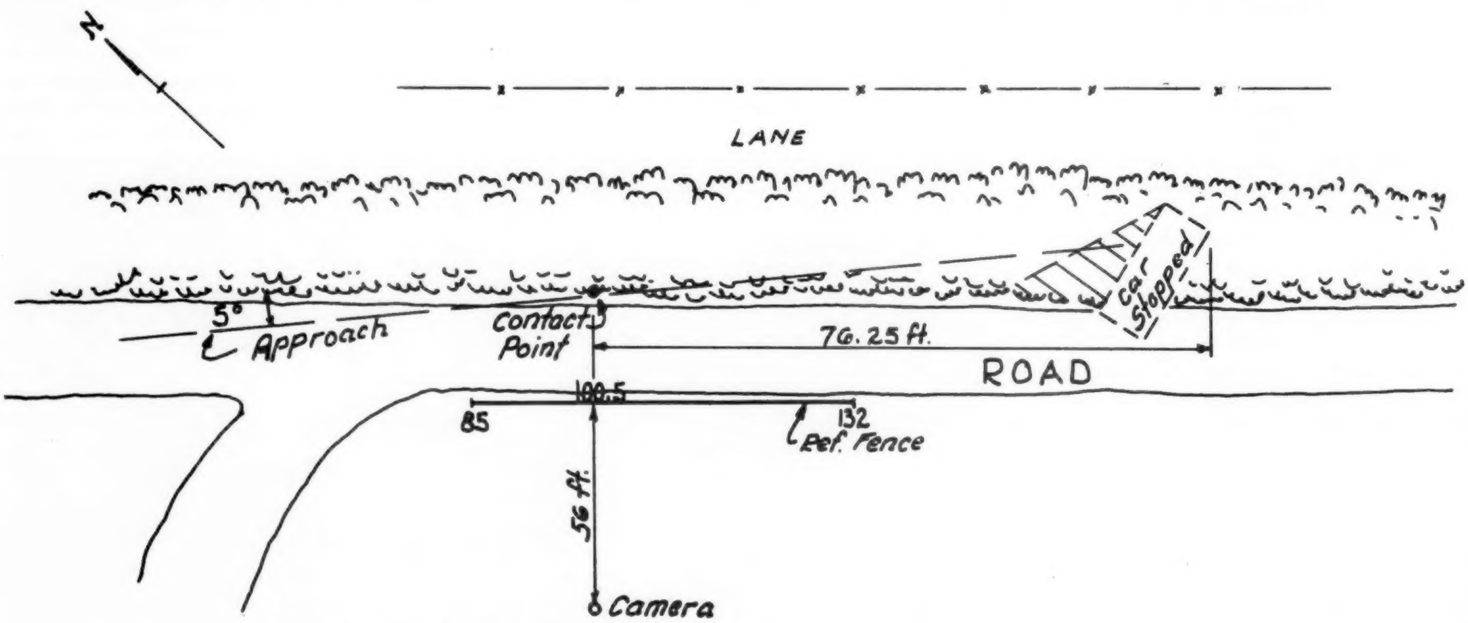

Figure 5.—Sketch of test No. 4 (5° angle approach at 30.2 miles per hour contact speed).

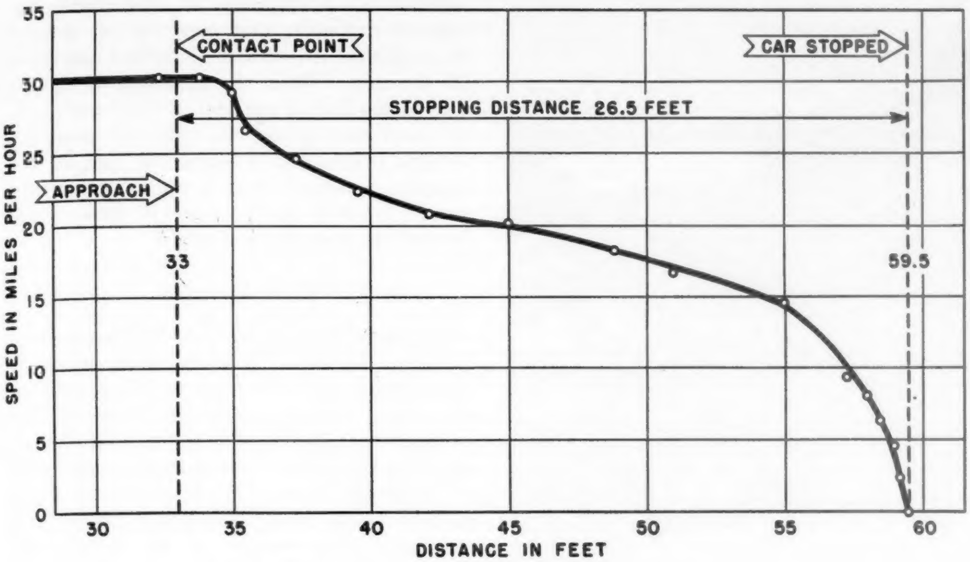

Figure 6.—Speed-distance curve for test No. 1.

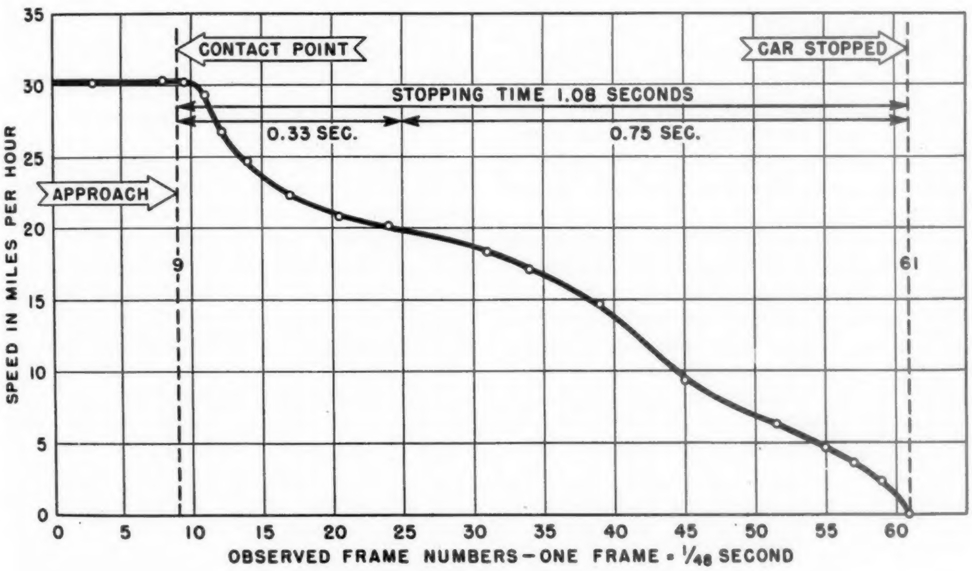

Figure 7.—Speed-time curve for test No. 1.

apparent that upon contact with the bushes, the car speed decreased rather rapidly to about 20 miles per hour in a distance of 12 feet and in a time interval of 0.33 second. The average deceleration for the period was 22.4 feet per second per second or 0.69 *g*. The car speed then dropped from 20 miles per hour to zero in a time interval of 0.75 second, which is equivalent to an average deceleration of 19.6 feet per second per second or 0.61 *g*. The overall stopping time was 1.08 seconds.

The maximum error in reading the distance traveled in one frame was generally observed to be plus or minus 0.1 foot. For the 48 fps film this amounted to plus or minus 3.27 m.p.h. Where the 128 fps film was used for evalutation, an error in distance observation of 0.1 foot produced a possible error in speed of plus or minus 8 m.p.h. However, the maximum deviation from the mean of the computed speeds, using the 128 fps film, was 6 m.p.h.

In several angle tests, the stopping distance was too great to be recorded by the fixed cameras. In other instances the car path curved sharply near the end of the run, which prevented complete evaluation of the car performance from the film record.

The evaluation methods and procedures were the same for the summer and winter tests. During the winter series the temperature was so low that all cameras seemed to be running slow. Later film evaluation proved the foregoing to be true, consequently the film results were not used. Stopping time for the winter tests was obtained solely from the accelerometer records.

Accelerometer-Tape Evaluation

The wax-coated accelerometer tapes for each test were photographed and the prints were projected and traced on cross-section paper. The enlarged graph was useful in determining the several peak deceleration values in relation to the time of occurrence and the average deceleration for the duration of the tests.

An enlarged graph of the longitudinal section of the chart for test No. 1 is shown in figure 8. Although this graph is not necessarily typical for all tests, it does indicate the type of data obtained from similar graphs prepared for all succeeding tests. It is seen that the maximum peak was 1.77 *g*. The elapsed time from the crash point for any peak and the total elapsed stopping time can be read from this graph. In this instance the maximum peak occurred about 0.34 second from the contact point. The overall stopping time was about 1.08 seconds. This stopping time is almost identical with that determined from the film evaluation of the same test, which was the case for all tests.

The average deceleration in the longitudinal plane was obtained by measuring the area under the curve with a planimeter and dividing the area by the base-line length between the point of contact and the point where the car came to rest. The average deceleration was determined for all tests in the longitudinal direction by this method and was used as a source of comparison of performance of the car and the bushes. In figure 8, it is indicated to be 1.05 *g*.

The evaluation of the tape for the single component accelerometer was read directly and the peak results compared with the vertical values obtained from the graph of the three-component accelerometer. In general, the single component accelerometer maximum range was inadequate, since the peak vertical acceleration was usually greater than 1 *g*. When the peak vertical acceleration was less than 1 *g*, the values of both instruments were in substantial agreement.

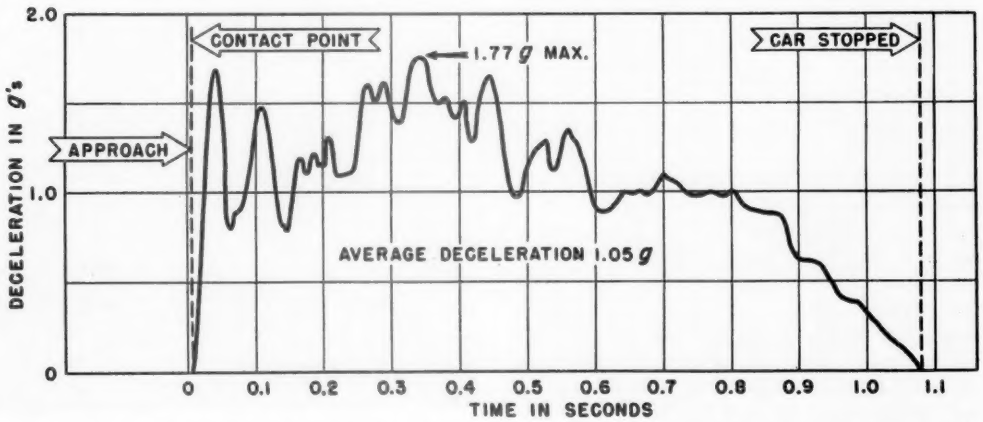

Figure 8.—Longitudinal deceleration during test No. 1, expressed in terms of gravity (g).

Figure 9.—Final position of test car after test No. 6.

Typical Performance Characteristics

During the first part of the deceleration period for the head-on tests, the canes of the bushes sheared about 3 to 4 feet above ground. Some of the bushes were pulled out and these plus the sheared canes and broken branches were pushed ahead of the car. The results of these actions are shown on the cover picture and in figure 9 for test No. 6. In this test the contact point was at 12 on the reference fence.

As the loose mass was accumulated and as the car pushed the entangled mass ahead, the forward bushes were either pushed down or were stripped of their foliage, as shown in figure 9. In the last one-third of the stopping interval, the loose mass was compressed with little forward movement, which resulted in the car being stopped very gradually. A tendency for the car to "ride up" on the bushes and the softness of the ground under the bushes make it doubtful that the use of brakes would have materially shortened the stop. In two tests where the hedge was wider than 8 feet, and where smaller seedling plants grew outside the axis, the car cut a path along the axis, leaving a fringe of bushes on each side, as shown in figure 10 for test No. 7.

Although the hedge was devoid of leaves in the winter tests, there appeared to be little, if any, significant difference in the stopping performance of the hedge between the summer and winter tests. With the ground frozen, there did appear to be more roots left in the ground.

Two angle tests at 5 degrees, one at 10 degrees, and one at 20 degrees were performed in the summer series. The speed of contact for these tests was planned for a maximum of 30 m.p.h. because the hedge was narrow and not too dense. In all angle tests, the fringe of the bushes did not slow the car appreciably; it was not until the front of the car encountered the central mass of the hedge that the vehicle was noticeably retarded. Since relatively few bushes were in the path of the car, they were either sheared or torn out. There was no massive accumulation of loose bushes to compress, as described previously. Had there been several parallel rows of bushes instead of one, the performance would have been similar to a head-on crash once the vehicle was turned into the hedge.

The car was stopped within the hedge on both 5- and 10-degree angle tests and passed through the hedge on the 20-degree angle test. There was no indication that the bushes tended to deflect the car. Actually, the retarding effect of the bushes caused the car to swing inward on an arc, as shown in figure 5.

During the summer and winter tests, there were three different drivers employed. One common observation was of considerable significance; namely, that once the car entered the hedge the driver had no further control of the steering. When the approach of the car was on the line of the axis of the bushes, the car path throughout the test was generally straight. However, toward the end of the stopping period the rear of the car frequently moved laterally as the mass of loose hedge became thoroughly compressed.

Test Results

A summary of the test data is given in table 1 for the 12 tests. A study of the data obtained from any one test, or a comparison of the results of similar tests, must be made with caution because there were several factors affecting the results that did not remain constant for each test. Three of the more important factors were: The width, height, and compactness or density of the bushes; the pattern of the path the test car followed on the approach, and during the stopping period; and the condition of the ground surface on the approach and within the hedge. In order to help evaluate the test results contained in table 1, a brief discussion of each test follows.

Summer tests, head-on approach

Test No. 1 was made as a pilot run at low speed to study the performance and to develop procedure. The approach to the axis of the hedge required that the driver execute a reverse curve maneuver of about 9 feet laterally in 60 feet of distance to crash the hedge parallel to the hedge axis. The car tracks indicated that the approach was not parallel to and on the hedge axis; consequently, the rear of the car moved gradually sidewise about 3 feet toward the end of the stopping period. The front of the vehicle remained on the axis.

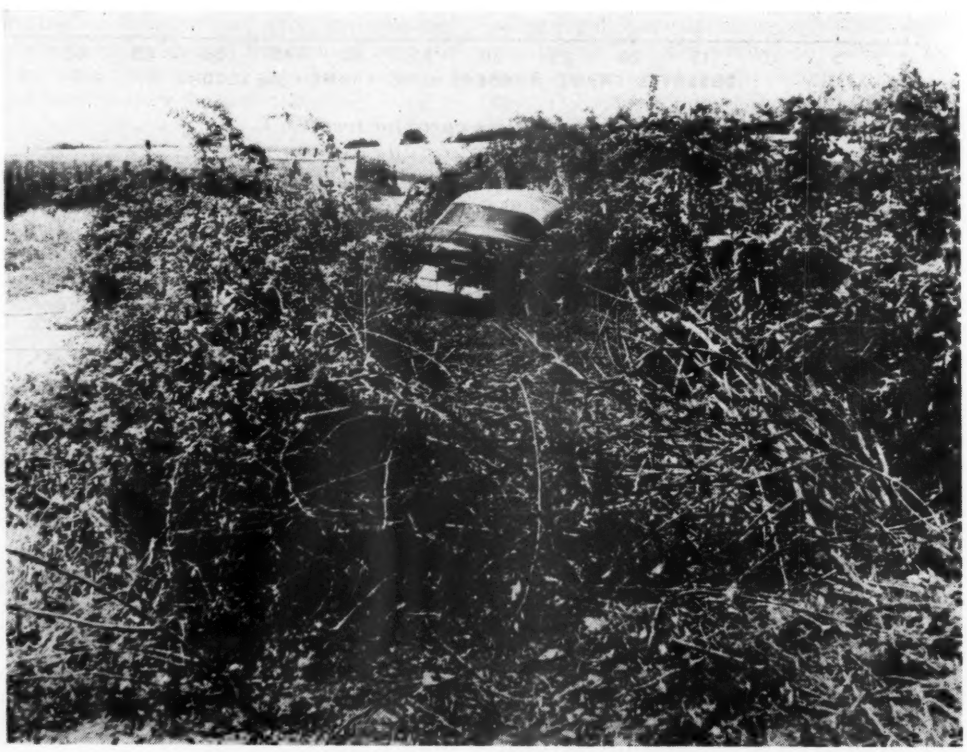

Figure 10.—Final position of test car after test No. 7.

Table 1.—Summary of crash test results [1]

Test No.	Collision course	Contact speed	Stopping distance	Stopping time	Longitudinal deceleration [2]			Maximum acceleration [2]	
					Average	Maximum	Time from contact	Vertical	Lateral
		M.p.h.	*Ft.*	*Sec.*	*g*	*g*	*Sec.*	*g*	*g*
1	Head on	30.3	26.5	1.08	1.05	1.77	0.33	1.25	1.0
2	do	30.5	26.0	1.25	.5	------	------	.7	.25
3	do	21.0	17.0	1.02	------	------	------	------	------
4	5° angle	30.2	76.2	2.8	------	.87	1.9	.5	.5
5	do	36.0	117	1.8	.75	1.40	.69	1.5	1.25
6	Head on	35.5	51.8	1.91	.68	2.72	.21	1.0	.5
7	do	47.8	57.2	1.94	.93	2.24	.38	1.39	2.12
8	20° angle	28.4	------	------	------	1.09	.13	1.33	.7
9	10° angle	27.0	56+	1.62	------	1.71	1.00	1.12	.91
10	Head on	35.0	50.1	1.50	------	------	------	------	------
11	do	22.0	16.3	1.26	.53	.82	.25	.5	.5
12	do	50+	76.5	2.14	.64	1.74	.32	1.23	1.27

[1] Tests 1-9 were conducted during the summer, and tests 10-12, during the winter.
[2] Decelerations and accelerations were recorded by three-component accelerometer.

This sidewise movement probably would have been contained had the hedge been wider.

Most of the bushes on the car path were pulled out because the soil was dry and loose. Some bushes were sheared. The measured stopping distance of 26.5 feet and other data are given in table 1. The entire hood of the car up to the windshield was buried in a compressed mass of tangled rose bushes, but the car was removed under its own power. An area about 20 feet in length was swept clean of bushes.

Test No. 2 was a low-speed test intended to duplicate test No. 1. Unfortunately the car struck to the right of the hedge center, causing the rear end to slide severely to the right. The sliding action which developed rendered the test unusable for comparative purposes with respect to the accelerometer data. The stopping distance of 26.0 feet closely approximated that for test No. 1. The final position of the car is shown in figure 11.

Test No. 3 was planned to replace test No. 2, using a straight approach over adjacent pastureland. The available distance proved to be insufficient to develop the planned approach speed; however, the rear end did not slide to the right. This test definitely proved that the angle of approach coupled with the loose soil was causing the sliding action in previous tests. The accelerometers were not employed on this test which accounts for the absence of such data in table 1.

Summer tests, angle approach

Tests Nos. 4 and 5 were conducted as 5-degree angle tests for duplicate study. In both tests the stopping distances were excessive because the distances were measured from the point where the car first touched the fringe of overhanging bushes. The path of the car was straight until the central bush mass was encountered; thereafter the path curved into the central hedge structure.

In test No. 4, the car was stopped by the hedge and remained within the hedge mass, as illustrated in figure 5, even though the bushes were thin and less dense than at other locations. In test No. 5, the rear of the car swung rather violently in an arc when it struck a large central root mass. It stopped perpendicular to the axis of the hedge 117 feet beyond the contact point. Had the approach speed been higher, the tests would have been extremely hazardous because of fixed objects located on the far side of the hedge.

Summer tests, head-on approach

Test No. 6 was planned for a contact speed of 50 m.p.h.; however, the approach surface was soft and irregular even after preparation, and the approach speed decreased rapidly to 35.5 m.p.h. at contact. The hedge was wide and dense. This test demonstrated most effectively the desirable properties of the multiflora rose hedge as a crash barrier.

The highest deceleration, 2.72 *g*, occurred in this test. It is significant to note that 0.21 second was required to develop this peak value from the instant of impact. The gradual buildup to the peak deceleration is an important advantage demonstrated by this and other tests.

In this particular test the individual bushes were closer than usual, evenly spaced, and the canes were large, as shown in figure 9. The average diameter was about three-quarters of an inch and the maximum was 1⅜ inches. The bushes were counted before and after the test and there were 26 bushes destroyed in the test. When the enlarged longitudinal section of the accelerometer record was analyzed, there were 26 distinct peaks averaging 1.25 *g* over about two-thirds of the stopping distance of 51.8 feet. Field notes indicated that the bushes were sheared completely in the first half of the stopping distance.

These observations indicate that each bush offered a distinct and nearly equal resistance in overcoming the kinetic energy of the car, which was finally reduced to zero by the compression of the loose entangled mass. A study of the speed-distance and speed-time curves indicated that the compression of the mass started at about 47 feet or 0.92 second from the point of contact.

Test No. 7 was similar to test No. 6 except that the contact speed was 47.8 m.p.h. In order that the effect of a discontinuous hedge be studied, 10 feet of hedge were removed for the full width at a point 55 feet ahead of the contact point. This distance was selected on the basis of the stopping distance observed in previous tests and on the characteristics of the hedge, which was wider and more dense than any section previously tested.

The car was declutched about 15 feet ahead of the contact point. It followed a straight path along the axis of the bushes until near the end of the run, when the rear end moved laterally until it came to rest at an angle of about 45 degrees with the axis. The final position of the car is shown in figure 10 as well as the path made through the bushes. About 3 to 4 feet of partially damaged bushes can be seen on both sides. The mass of bushes above the hood of the car had not yet settled at the time of the picture.

The 10-foot gap, previously described, was partially filled. It was found that the compressed mass was pushed into the opening only 6 feet on the center position and that no intrusion occurred on either edge of the hedge. Since the gap was only partially filled with the compressed mass, it may be concluded that the unsheared canes ahead of the car prevented the mass from being pushed forward, consequently the mattress was pushed upward as it was being compressed. It was

Figure 11.—Final position of test car after test No. 2.

generally noted that the front of the car usually "rode up on" the mass in the last short interval of the deceleration period and that the front end settled slowly after the car stopped.

A study of a photographic enlargement of the accelerometer record indicated a stopping time of 2.03 seconds, which was in fair agreement with the 1.94 seconds obtained by film analysis. This study also revealed several peak values in longitudinal deceleration, the maximum being 2.24 g at 0.38 second after contact. The longitudinal deceleration curve for this test was not so erratic as that of test No. 6. It appears from the graph that the last 0.8 second was consumed in compressing the loose mass of bushes during which time very little shearing action occurred.

As noted in table 1, this test produced the maximum peak values of vertical and lateral acceleration. The vertical g factor was 1.39, occurring 0.46 second after contact. There were other vertical peak values spread over the graph which had values of 1.0 to 1.14 g. These observations are in agreement with the car performance which showed a violent pitching action in the longitudinal plane. On the lateral acceleration record a severe maximum g factor of 2.12 occurred 0.93 second after contact. A comparison of the enlarged accelerometer record in each plane indicated a rapid and violent lateral movement or skidding of the rear end of the test car. However, the driver did not report any serious acceleration reaction from the seat or shoulder belts.

Summer tests, angle approach

Test No. 8 was a 20-degree angle test. The contact speed was planned for 30 m.p.h. because it was expected that the car would swerve through the thin 8-foot-wide hedge. The car passed completely through as predicted and the brakes were applied outside the hedge to prevent serious injury. As a result, little reliable data for evaluation were available.

The car followed a straight line for about 20 feet, after which it veered left on an arc. It was finally stopped 43 feet from the contact point measured along the axis of the hedge. Figure 12 shows the vehicle after it had crashed through and was stopped with the help of its brakes.

Test No. 9 was run on a section of the hedge shown in the foreground of figure 1. It was made on a 10-degree angle approach and was planned for a speed of 30 m.p.h. The performance of the car was similar to that for previous angle tests. The car was stopped by the hedge, but the impact with the central mass caused the rear of the car to swing violently through an arc of about 80 degrees to the axis. Had the hedge at this point been wider and more dense, a more gradual stop would probably have occurred.

Winter tests, head-on approach

Test No. 10 was planned to duplicate the speed obtained in test No. 6. It is noted in table 1 that the stopping distance and elapsed time for these tests were quite similar. The hedge was similar in width and density although the ground within the hedge on test No. 10 was quite irregular and many rocks were partly exposed. The approach was on a slight downgrade and there was a considerable cross slope to the ground. Although the bushes were devoid of leaves, the performance of the hedge was similar in all respects to that described for test No. 6.

Test No. 11 was planned to duplicate the summer test No. 3, which had a contact speed of 21 m.p.h. Because the remaining hedge in this section was located on very rough and rock-strewn ground, it was too dangerous to run high-speed tests which would have required long stopping distances. The results of tests Nos. 3 and 11, as indicated in table 1, were quite similar.

Test No. 12 was planned for a contact speed of 50 m.p.h. on the remaining section of hedge suitable for testing. This test was run on the far end of the hedge shown in figure 1. The hedge was thin but measured 9 feet wide and 108 feet long. There were 36 individual bushes in this length. The stopping distance, when compared to that of test No. 7, was

(*Continued on page 267*)

Figure 12.—Final position of test car after test No. 8. (Vehicle crashed through the hedge and was stopped with the aid of brakes.)

Traffic and Travel Trends, 1956

BY THE DIVISION OF HIGHWAY TRANSPORT RESEARCH
BUREAU OF PUBLIC ROADS

Reported by THOMAS B. DIMMICK,
Supervising Transportation Economist

Traffic studies undertaken by the Bureau in cooperation with the State highway departments are a continuing operation, and the vast amount of data resulting from these studies provides interested officials, both public and private, with an overall view of the use of the highways.

The trends reported in the annual series of articles relating to travel by passeger cars, trucks, and buses, volumes of freight transported over the highways, and frequencies of heavy gross loads and axle loads are of prime importance to agencies responsible for providing highway facilities.

In the last 5 years, 1951–56, travel on all roads and streets has increased 28 percent, with the greatest increase, 31 percent, occurring in rural areas as compared with 24 percent in urban areas. During this period, the growth of passenger-car travel exceeded all other types of vehicles as evidenced by increases of 29, 22, and 12 percent for passenger cars, trucks, and buses, respectively.

A considerable portion of this article is devoted to travel and loading practices observed on the main rural roads, which comprise about 12 percent of all rural mileage and carry over 67 percent of all rural traffic. Approximately two-thirds of all truck travel in rural areas was performed on these roads, of which about one-third was by truck combinations.

Average daily travel on the main rural roads totaled 650 million vehicle-miles in 1956, as compared with 625 million in 1955, a 4-percent increase. By principal geographical areas, the rates of increase in travel from 1955 to 1956 were 5.3 percent for the States in the eastern region, 2.6 percent for States in the central region, and 5.6 percent for States in the western region.

Passenger-car and bus travel on main rural roads increased 26 percent between 1951 and 1956; single-unit truck travel increased 22 percent; and travel by truck combinations increased 27 percent.

In 1956, 57 percent of all freight-carrying vehicles were loaded, and weighed an average of about 24,200 pounds. For the period 1951-56, weights of loaded single-unit trucks decreased over 3 percent, whereas those of loaded combinations increased about 6 percent.

Single-unit trucks in 1956 carried loads during 51 percent of their travel as compared with 60-65 percent during the prewar period, 1936-41. Combinations in 1956 were found to be loaded during 70 percent of their travel as compared with 72 percent in 1936.

Average loads carried by single-unit trucks increased from 1.86 tons in 1936 to 2.39 tons in 1956, a 28-percent increase, while combinations increased from 6.90 tons in 1936 to 11.51 tons in 1956, a 67-percent increase.

The volume of freight hauled in 1956 by single-unit trucks was 41.2 billion ton-miles as compared with 14.3 billion in 1936; combinations in 1956 hauled 130 billion ton-miles as compared with 13.7 billion in 1936. The 2-axle, 6-tire trucks, the principal load-carrying single-unit trucks, accounted for 25 percent of all truck travel in 1956, and less than 16 percent of the ton-mileage; truck-tractor and semitrailer combinations accounted for 30 percent of the travel and 67 percent of the ton-mileage.

Frequencies of freight-carrying vehicles weighing 30,000, 40,000, and 50,000 pounds or more reached a new high in 1956. Since 1936 the number of trucks in each 1,000 loaded and empty vehicles weighing 30,000 pounds or more have increased almost 5 times; for 40,000 pounds or more, over 13 times; and 50,000 pounds or more, 31 times. From 1951 to 1956, the frequencies increased 11, 24, and 45 percent, respectively.

Frequencies of axles weighing 18,000, 20,000, and 22,000 pounds or more show increases in 1956 over 1954 and 1955 but for the period 1951-56, there has been a decrease of 8, 15, and 14 percent in the three respective axle-weight categories.

THIS article, discussing the significance of annual changes and trends in highway travel, is a continuation of a series that have been published each year since 1946. A comprehensive study of automobile and truck usage of the highways is presently underway. One of the provisions of the Federal-Aid Highway Act of 1956, particularly section 210 of the Highway Revenue Act, requires, among other stipulations, that the Bureau of Public Roads inquire into the effects on design, construction, and maintenance of Federal-aid highways of the magnitude and frequency of occurrence in the traffic stream of vehicles of different sizes and weights. At this time, only limited data from this study are available for inclusion in this article, but a similar article to be published in 1958 will be based on much more complete information concerning highway usage.

In the 5-year period beginning in 1936, 47 of the 48 States in cooperation with the Bureau of Public Roads conducted surveys for a 12-month period to collect data which would supply comprehensive information concerning vehicle characteristics and travel habits. The measuring of road mileages, the counting of traffic by vehicle types, the weighing of trucks on rural roads, and the questioning of drivers concerning origin and destination and miles driven on different road systems during the preceding year supplied basic data from which a vast amount of information regarding travel habits, ton-miles of freight carried on rural systems, and vehicle-miles driven on all systems could be calculated for the period of the survey.

Since the original surveys were made, the States have used automatic traffic recorders continuously at a large number of locations and have adopted other continuing operations which provide data for estimating trends in traffic volumes. Periodic weighing operations, combined with manual classification counts of all vehicles passing the weighing stations, have been made which provide information concerning vehicle types and weights as well as their loading. By means of these trends annual estimates have been published showing for each year the travel on rural roads and city streets from 1936 to 1955.[1] By combining carried load with vehicle-mileage data on main rural roads, the ton-mileage of freight hauled on these highways has been estimated for each year. Sufficient data are not now available to justify publishing estimates of ton-mileage on local roads. No data have been collected in past surveys concerning loads carried on city streets, although the survey now underway should provide such information.

Travel Related to Economic Trend

The trends in travel on all rural roads and streets, motor-vehicle registrations, motor-fuel consumption, and gross national product (in 1947 dollars) are shown in figure 1 for the years 1936–56, inclusive, as a percentage of the 1950 totals. This chart indicates that with the exception of the war years and the early postwar period, the trend of travel and its related factors of registration and fuel consumption followed closely the economic trend, as represented by the gross national product, until 1954. In 1954 the gross national product shows a downtrend, the total adjusted to the 1947 dollar decreasing from $306.6 billion in

[1] See previous articles on traffic in PUBLIC ROADS: Vol. 29, No. 5; vol. 28, No. 11; vol. 27, Nos. 6 and 11; vol. 26, Nos. 5 and 11; vol. 25, Nos. 3, 7, and 12; vol. 24, No. 10; and vol 23, No. 9.

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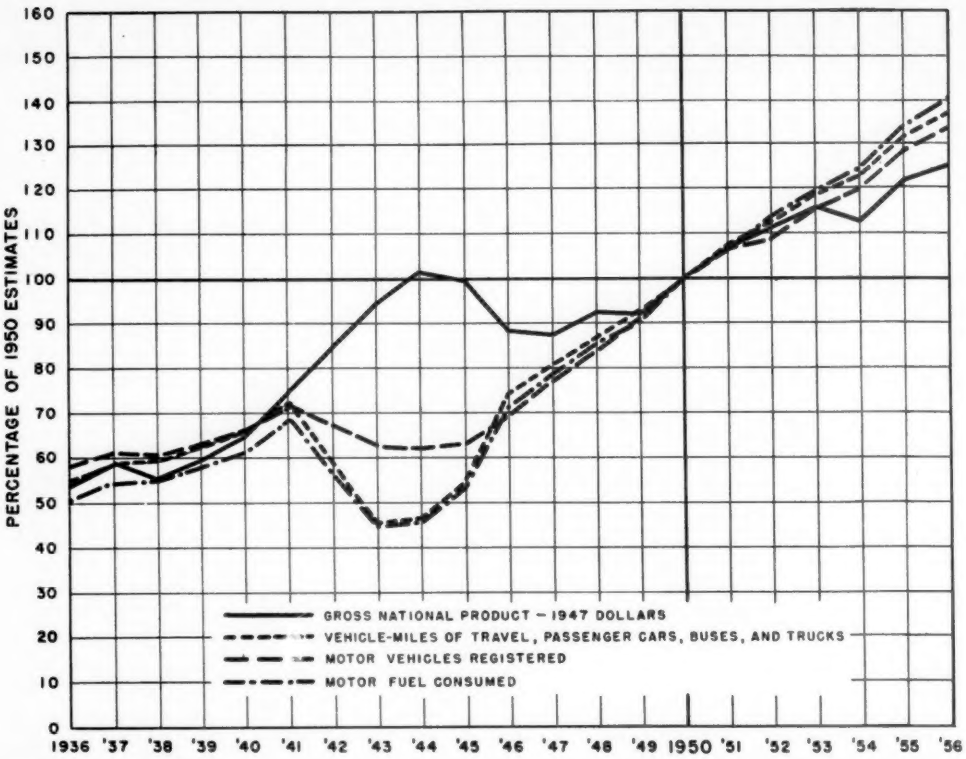

Figure 1.—Total travel, motor-vehicle registration, motor-fuel consumption, and gross national product, 1936–56, as a percentage of the respective amounts in 1950.

1953 to $300.8 billion in 1954, or 1.9 percent. At the same time, total travel increased 3.0 percent while registrations and fuel consumption both increased 3.7 percent.

From 1954 to 1955, the adjusted gross national product increased 7.2 percent; total travel increased 7.6 percent; registrations, 7.5 percent; and fuel consumption, 7.7 percent. Thus all of the trends were again about parallel. The 1956 figures indicate that all of the trends for the indices considered were again leveling off. Increases in 1956 were only 2.5 percent for the adjusted gross national product, 4.1 percent for total travel, 4.0 percent for vehicle registrations, and 5.2 percent for motor-fuel consumption. Thus once again as in 1954, the index of the national economy was not fully reflected in the indices of highway usage.

A comparison of vehicle-miles of travel on all roads and streets by 5-year periods commencing in 1936 is given in table 1. Probably the most significant relation shown by this table is the greater increase of travel in most periods by trucks and truck combinations in comparison with passenger cars and buses. Travel by trucks and truck combinations in 1956 was 182 percent greater than in 1936, while during that period passenger-car travel increased 143 percent, bus travel increased 95 percent, and total travel increased 149 percent. Trucks and truck combinations accounted for 16.3 percent of all rural and urban travel in 1936, and 18.5 percent in 1956.

In contrast with the overall trends of travel for the 20-year period, 1936–56, the 1951 and 1956 vehicle-mileage figures show that in the last 5-year period the rates of growth of passenger-car travel and of truck and truck-combination travel were reversed from that found in the third 5-year period (1946–51). For instance, passenger-car travel in 1956 was 29 percent higher than in 1951, while travel by trucks and truck combinations was only 22 percent higher; the rates of increase from 1946 to 1951 were 40 percent for passenger cars and 69 percent for trucks and truck combinations.

Travel on All Roads and Streets

Table 2 shows the estimated travel in 1956 on main rural roads, local rural roads, and urban streets for passenger cars, buses, and trucks, together with the number of vehicles registered and quantity of fuel consumed on the highways. The travel figures were obtained mainly by applying trends obtained in 1956 from the automatic traffic recorders to the 1953 data which were derived from the various State reports submitted for the nationwide highway study of that year. Actual vehicle-mileage totals on the various turnpikes were obtained from reports of the turnpike authorities. Finally, minor adjustments were made in the totals of local rural road and city street travel to bring the total travel figure for the year to the total of the latest estimates submitted by the States and the District of Columbia. Such adjustments are necessary periodically to add the small but important increment of travel on improved or newly constructed sections of local roads and streets in expanding fringe areas where traffic counts ordinarily are not made.

Urban travel comprised about 44 percent of the total 1956 travel. Since 1951 the relation between urban and rural travel has remained nearly constant, but in the earlier years a different division existed. In 1946, urban travel constituted almost 50 percent of the total travel; 49 percent in 1941; and 51 percent in 1936. These data show that in the period immediately previous to 1951, the volume of rural travel increased at a more rapid rate than urban travel, while from 1951 through 1956 the two rates of increase have been approximately equal.

The concentration of truck travel on main rural roads also may be noted in table 2. These main roads, which comprise about 12 percent of the mileage of all roads and streets, carry over 43 percent of all truck travel compared to 37 percent for passenger cars. As would be expected, the larger portion of the heavier vehicles use the main highways. Approximately 32 percent of the truck traffic on these facilities was made up of combination-type vehicles, but on the local roads the combinations accounted for only 10 percent of the truck traffic. To illustrate further the relation of truck travel on the two classes of rural roads, the average daily number of trucks traveling at any point on the main rural highways in 1956 was 238 single-unit trucks and 114 truck combinations; on local rural roads, the averages were 22 single-unit trucks and only 3 combinations. Sufficient data concerning the vehicle types using city streets are not yet available to make a similar distribution possible in urban areas.

Table 1.—Comparison of estimated vehicle-miles of travel on all roads and streets in 1936, 1941, 1946, 1951, and 1956

Year	Total travel, vehicle-miles	Passenger-car travel		Bus travel		Truck and truck-combination travel	
		Vehicle-miles	Percentage of total travel	Vehicle-miles	Percentage of total travel	Vehicle-miles	Percentage of total travel
	Millions	*Millions*		*Millions*		*Millions*	
1936	252,128	208,654	82.76	2,367	0.94	41,107	16.30
1941	333,612	275,839	82.68	2,820	.85	54,953	16.47
1941:1936 ratio	*1.32*	*1.32*	*1.00*	*1.19*	*.90*	*1.34*	*1.01*
1946	340,880	280,597	82.31	4,053	1.19	56,230	16.50
1946:1941 ratio	*1.02*	*1.02*	*1.00*	*1.44*	*1.40*	*1.02*	*1.00*
1946:1936 ratio	*1.35*	*1.34*	*.99*	*1.71*	*1.27*	*1.37*	*1.01*
1951	491,093	392,131	79.85	4,118	.84	94,844	19.31
1951:1946 ratio	*1.44*	*1.40*	*.97*	*1.02*	*.71*	*1.69*	*1.17*
1951:1941 ratio	*1.47*	*1.42*	*.97*	*1.46*	*.99*	*1.73*	*1.17*
1951:1936 ratio	*1.95*	*1.88*	*.96*	*1.74*	*.89*	*2.31*	*1.18*
1956	627,843	507,138	80.78	4,605	.73	116,100	18.49
1956:1951 ratio	*1.28*	*1.29*	*1.01*	*1.12*	*.87*	*1.22*	*.96*
1956:1946 ratio	*1.84*	*1.81*	*.98*	*1.14*	*.61*	*2.06*	*1.12*
1956:1941 ratio	*1.88*	*1.84*	*.98*	*1.63*	*.86*	*2.11*	*1.12*
1956:1936 ratio	*2.49*	*2.43*	*.98*	*1.95*	*.78*	*2.82*	*1.13*

Table 2.—Estimate of motor-vehicle travel in the United States by vehicle types in the calendar year 1956

Vehicle type	Motor-vehicle travel: Main rural road travel	Motor-vehicle travel: Local rural road travel	Motor-vehicle travel: Total rural travel	Motor-vehicle travel: Urban travel	Motor-vehicle travel: Total travel	Number of registered vehicles [1]	Average travel per vehicle	Motor-fuel consumption: Total [2]	Motor-fuel consumption: Average per vehicle	Average travel per gallon of fuel consumed
	Million vehicle-miles	*Million vehicle-miles*	*Million vehicle-miles*	*Million vehicle-miles*	*Million vehicle-miles*	*Thousands*	*Miles*	*Million gallons*	*Gallons*	*Miles/gal.*
Passenger cars [3]	185,901	89,785	275,686	231,452	507,138	54,249	9,348	35,326	651	14.36
Buses:										
Commercial	1,114	303	1,417	1,854	3,271	95	34,432	673	7,084	4.86
School and nonrevenue	663	521	1,184	150	1,334	160	8,338	129	806	10.34
All buses	1,777	824	2,601	2,004	4,605	255	18,059	802	3,145	5.74
All passenger vehicles	187,678	90,609	278,287	233,456	511,743	54,504	9,389	36,128	663	14.16
Trucks and combinations	50,070	24,022	74,092	42,008	116,100	10,737	10,813	13,978	1,302	8.31
All vehicles	237,748	114,631	352,379	275,464	627,843	65,241	9,623	50,106	768	12.53

[1] Registration figures differ slightly from those in Bureau of Public Roads table MV-1 because of adjustments in classification in a few States of lightweight farm trucks.
[2] Total fuel consumed differs from that given in Bureau of Public Roads table G-21 because of adjustments to cover estimated amounts used by motorcycles.
[3] Includes taxicabs.

Data have been collected concerning the loads carried on local roads, but such studies were limited in scope and therefore not as reliable as the information on main roads. Local road mileage far exceeds that of the main roads, yet estimates indicate that truck travel on main roads was more than double and ton-mileage was more than four times the amount carried on local roads. Because of the limited data and the relative unimportance of the local road mileage from a freight-carrying standpoint, discussion in subsequent sections of this article is confined to the main rural roads.

Main Rural Road Travel Increases

Figure 2 shows the annual vehicle-miles of travel by all vehicles on main rural roads by 12-month periods ending each month (moving average) from the end of 1936, the first year of the planning surveys, to August 1957. This method of presentation eliminates the seasonal fluctuations. From the end of 1946 through 1951, the increase of each year's traffic over the previous year averaged approximately 10 percent. Since 1951 the annual increases over the previous year have been somewhat smaller: 1952, 7 percent; 1953, 5 percent; 1954, 2 percent; 1955, 5 percent; 1956, 4 percent; and the first 8 months of 1957, 3 percent.

The average daily vehicle-miles of travel on main rural roads by months are shown in figure 3 for 1955, 1956, and the first 8 months of 1957. The graph shows that travel in 1956 was greater month by month for the United States as a whole than it was in the corresponding months of the previous year. Likewise for the first 8 months of 1957, travel exceeded that in 1956.

The average daily travel on main rural roads in 1956 totaled 650 million vehicle-miles as compared with 625 million vehicle-miles in the previous year, a 4.0-percent increase. A comparison of average daily travel by census regions [2] in 1956 and 1955

[2] *Eastern region.*—New England division: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont. Middle Atlantic division: New Jersey, New York, and Pennsylvania. South Atlantic division: Delaware, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, and West Virginia. *Central region.*—East North Central division: Illinois, Indiana, Michigan, Ohio, and Wisconsin. East South Central division: Alabama, Kentucky, Mississippi, and Tennessee. West North Central division: Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota. West South Central division: Arkansas, Louisiana, Oklahoma, and Texas. *Western region.*—Mountain division: Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming. Pacific division: California, Oregon, and Washington.

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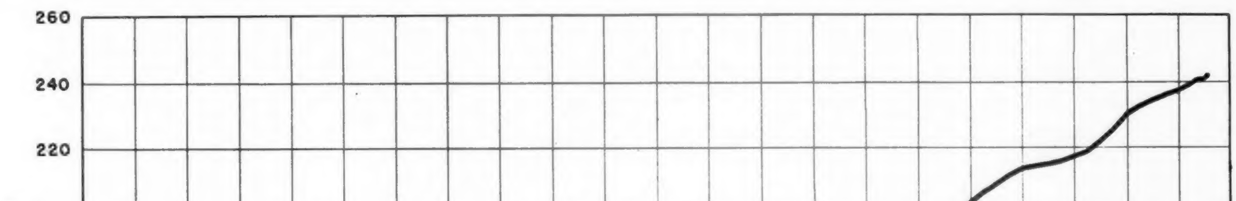


Figure 2.—Vehicle-miles of travel on main rural roads by 12-month periods ending each month, 1936 to August 1957.

STATE LEGAL MAXIMUM LIMITS OF MOTOR VEHICLE SIZES A

Prepared by the Bureau of Publi

Line	State	Width inches[1]	Height ft.-in.	Length—feet[2]: Single unit: Truck	Length—feet[2]: Single unit: Bus	Length—feet[2]: Truck tractor semi-trailer	Length—feet[2]: Other combination	Number of towed units[3]: Semi-trailer	Number of towed units[3]: Full trailer	Number of towed units[3]: Semi-trailer and full trailer	Axle load—pounds: Single: Statutory limit	Axle load—pounds: Single: Including statutory enforcement tolerance	Axle load—pounds: Tandem: Statutory limit	Axle load—pounds: Tandem: Including statutory enforcement tolerance	Type of restriction
1	Alabama	96	[6]12-6	35	40	50	NP	1	NP	NP	18,000	19,800	36,000	39,600	Table
2	Arizona	96	13-6	40	40	65	65	1	1	2	18,000		32,000		Table
3	Arkansas	96	13-6	35	40	50	50	1	1	NP	18,000	[7]18,500	32,000	32,500	Spec. maximum[8]
4	California	96	13-6	35	[9]35	[10]60	60	NR	NR	NR	18,000		32,000		Table
5	Colorado	[11]96	13-6	35	40	60	60	1	2	2	18,000		36,000		Formula-spec. limits
6	Connecticut	102	12-6	45	45	[12]45	NP	1	NP	NP	22,400	22,843	36,000	36,720	Spec. lim.-tire cap.
7	Delaware	96	[6]12-6	35	42	50	60	1	1	2	20,000		36,000		Table-spec. limits [13]
8	District of Columbia	96	12-6	35	35	50	50	1	1	NP	22,000		38,000		Table
9	Florida	96	[6]12-6	[14]35	40	50	50	1	1	NP	20,000	22,000	40,000	44,000	Table
10	Georgia	96	13-6	[15]+39	[15]+45	48	48	1	1	NP	18,000	20,340	36,000	40,680	Spec. maximum[16]
11	Hawaii	[18]108	13-0	40	40	55	65	1	1	2	24,000		32,000		Formula[17]
12	Idaho	96	14-0	35	[19]40	60	65	1	1	2	[20]18,000		[20]32,000		Table[20]
13	Illinois	96	13-6	42	42	50	50	1	1	2	[21]18,000		32,000		Spec. lim.-tire cap.
14	Indiana	96	13-6	36	40	50	50	1	1	2	[23]18,000	[23]19,000	[23]32,000	[23]33,000	Spec. lim.-tire cap.[2
15	Iowa	96	[6]12-6	35	[19]40	50	NP	1	NP	NP	18,000	18,540	32,000	32,960	Table
16	Kansas	96	12-6	35	[19]40	50	50	1	1	NP	18,000		32,000		Table
17	Kentucky	96	[25]12-6	[26]35	[26]35	[27]48	NP	1	NP	NP	18,000	[28]18,900	32,000	[28]33,600	Spec. lim.-tire cap.[2
18	Louisiana	96	[6]12-6	35	[19]40	50	60	1	1	NP	18,000		32,000		Axle lim.-tire cap.
19	Maine	96	[30]12-6	50	50	50	50	1	1	NP	22,000		32,000		Table-tire cap.
20	Maryland	96	[6]12-6	55	55	55	55	NR	NR	NR	22,400		[31]40,000		Formula
21	Massachusetts	96	NR	35	[19]40	45	NP	1	NP	NP	22,400		36,000		Table-spec. limits
22	Michigan	96	[6]12-6	35	40	55	55	1	1	2	[33]18,000		[34]32,000		Axle lim.-tire cap.
23	Minnesota	96	[6]12-6	40	40	50	50	1	1	NP	18,000		32,000		Table
24	Mississippi	96	[6]12-6	35	40	[36]45	45	1	1	NP	18,000		28,650	[35]32,000	Table-tire cap.
25	Missouri	96	12-6	35	40	45	45	1	1	2	18,000		32,000		Table
26	Montana	[18]96	13-6	35	40	60	60	1	1	[37]2	18,000		32,000		Table
27	Nebraska	96	13-6	35	[19]40	50	50	1	1	NP	18,000	18,900	32,000	33,600	Table
28	Nevada	96	NR	NR	NR	NR	NR	NR	NR	NR	18,000	18,900	32,000	33,600	Table
29	New Hampshire	96	13-6	35	[19]40	45	45	NR	NR	NR	22,400		36,000		Tables-spec. limits
30	New Jersey	96	13-6	35	[39]35	45	[40]50	1	1	NP	22,400	23,520	32,000	33,600	Spec. limits
31	New Mexico	[41]96	13-6	40	40	65	65	1	1	2	21,600		34,320		Table
32	New York	96	13-0	35	[42]35	50	50	1	1	NP	22,400		36,000		Formula
33	North Carolina	96	[6]12-6	35	[19]40	[43]48	[43]50	1	1	NP	18,000	19,000	36,000	38,000	Spec. limits
34	North Dakota	96	13-6	[14]35	[19]40	50	50	1	1	NP	18,000		30,000		Formula
35	Ohio	96	[6]12-6	35	[19]40	50	60	1	NR	NR	19,000		[44]31,500		Formula
36	Oklahoma	96	13-6	35	45	50	50	1	1	NP	18,000		32,000		Table
37	Oregon	96	[45]12-6	35	[35]40	[46,35]55	[35]60	1	1	[35]2	[47]18,000		[47]32,000		Table [48]
38	Pennsylvania	96	[6]12-6	35	[19]40	50	50	1	1	NP	22,400	23,072	36,000	37,080	Spec. limits[49]
39	Puerto Rico	98	12-0	NS	NS	NS		NS	NS	NS	NS		NS		Spec. lim.-tire cap.
40	Rhode Island	102	12-6	40	40	50	50	1	1	NP	22,400		NS		Spec. limits
41	South Carolina	96	[54]12-6	[14]35	[19]40	50	60	1	1	NP	20,000		32,000		Table
42	South Dakota	96	13-0	35	40	50	60	1	1	NP	18,000		32,000		Table
43	Tennessee	96	12-6	35	40	45	45	1	[24]1	NP	18,000		32,000		Table
44	Texas	96	13-6	35	40	50	50	1	1	NP	18,000	18,900	32,000	33,600	Table
45	Utah	96	14-0	45	45	60	60	NR	NR	NR	18,000		33,000		Table
46	Vermont	96	12-6	50	50	50	50	1	1	NP	NS		NS		Spec. lim.-tire cap.
47	Virginia	96	[6]12-6	35	[35]40	50	50	1	1	NP	18,000		[56]32,000		Table
48	Washington	96	[5]12-6	35	[19]40	60	60	1	1	[57]2	18,000	[58]18,500	32,000	[58]33,000	Table-spec. lim.[59]
49	West Virginia	96	[6]12-6	35	[19]40	50	50	1	1	NP	18,000	18,900	32,000	33,600	Table
50	Wisconsin	96	[6]12-6	35	40	50	50	1	1	NP	18,000	[60]19,500	30,000	32,000	Table-formula[61]
51	Wyoming	96	13-6	40	40	60	60	1	1	2	18,000		32,000	[62]36,000	Table
	AASHO Policy	96	12-6	35	[19]40	50	60	1	1	NP	18,000		32,000		Table
Number of States	Higher	4	23	16	29	15	6	6	8	21	31		30		Formula
	Same	47	27	35	18	26	12	45	38	30	20		18		Table 3
	Lower	0	1	0	4	10	33	0	5	0	0		3		Specified limits 1

NP—Not permitted. NR—Not restricted. NS—Not specified.

[1] Various exceptions for farm and construction equipment; public utility vehicles; urban, suburban, and school buses; haulage of agricultural and forest products; at wheels of vehicles; for safety accessories, and on designated highways.

[2] Various exceptions for utility vehicles and loads.

[3] When not specified, limited to number possible in practical combinations within permitted length limits.

[4] Legally specified or established by administrative regulation.

[5] Computed under the following conditions to permit comparison on a uniform basis between States with different types of regulation:

A. Front axle load of 8,000 pounds.

B. Maximum practical wheelbase within applicable length limits:

(1) Minimum front overhand of 3 feet.

(2) In the case of a 4-axle truck-tractor semitrailer, rear overhand computed as necessary to distribute the maximum possible uniform load on the maximum permitted length of semitrailer to the single drive-axle of the tractor and to the tandem axles of the semitrailer, within the permitted load limits of each.

(3) In the case of a combination having 5 or more axles, minimum possible combined front and rear overhand assumed to be 5 feet, with maximum practical load on maximum permitted length of semitrailer, subject to control of loading on axle groups and on total wheelbase as applicable.

C. Including statutory enforcement tolerances as applicable.

[6] Auto transports 13 feet 6 inches.

[7] Does not apply to combinations of adjacent load-carrying single axles.

[8] 56,000 pounds on load-carrying axles, exclusive of steering-axle load.

[9] On specific routes in urban or suburban service under special permit from P.U.C. 40 feet, also 3-axle buses with turning radius less than 45 feet without restriction.

[10] Limited by 40-foot maximum length of semitrailer to 55-foot practical maximum length in combination.

[11] Buses 102 inches.

[12] Truck tractor and housetrailer 50 feet.

[13] Legal limit 60,000 pounds.

[14] Three-axle vehicles 40 feet.

[15] Truck 39 feet 6 1/2 inches; bus 45 feet 2.4 inches.

[16] 63,280 pounds maximum, except on roads under Rural Roads A

[17] 700 (L+40) when L is 18' or less; 800 (L+40) when L is gre
structures with span of 20' or over.

[18] Buses 102 inches on highways of surfaced width at least 20

[19] Less than three axles 35 feet.

[20] Special limits for vehicles hauling timber and timber prod
cultural products including livestock; single axle 18,900 pound
vehicle with 3 or 4 axles permitted 66,000 pounds maximum at 2
permitted 79,000 pounds maximum at 43-foot axle spacing.

[21] On designated highways; 16,000 pounds on other highways.

[22] Without tandem axles 45,000 pounds.

[23] On designated highways: single axle 22,400 pounds, tandem
total of all excesses of weight under one or more limitations

[24] Limited to 3,500 pounds.

[25] On designated highways; 11 feet 6 inches on other highways

[26] On designated highways; trucks 26.5 feet and buses 30 feet

[27] Class AA highways; 45 feet on other highways.

[28] Class AA highways only.

[29] Maximum gross weight on Class A highways 42,000 pounds; on

[30] Including load 14 feet.

[31] Spaced less than 48 inches 36,000 pounds.

[32] Subject to axle and tabular limits.

[33] Single axle spaced less than 9 feet from nearest axle limi

[34] On designated highways only and limited to one tandem axle

[35] On designated highways only.

[36] Auto transports permitted 50 feet.

[37] Semitrailer and semitrailer converted to full trailer by m

[38] Dual-drive axles; otherwise 40,000 pounds.

SIZES AND WEIGHTS COMPARED WITH AASHO STANDARDS

eau of Public Roads, July 1, 1957

Gross weight limit				Specified maximum gross weight—pounds[4]						Practical maximum gross weight—pounds[5]						
		Applicable to:		Truck		Truck-tractor semitrailer				Truck		Truck-tractor semitrailer				
f restriction	Formula or equation	Any group of axles	Total wheel base only	2-axle	3-axle	3-axle	4-axle	5-axle	Other combi-nation	2-axle	3-axle	3-axle	4-axle	5-axle	Other combi-nation	Line
			X							27,800	47,600	47,600	60,010	64,650	NP	1
		Under 18'	Over 18'							26,000	40,000	44,000	58,000	72,000	76,800	2
aximum[8]										26,500	40,500	45,000	59,000	65,000	65,000	3
		Under 18'	Over 18'							26,000	40,000	44,000	58,000	72,000	76,000	4
-spec. limits	800 (L+ 40)		X	30,000	46,000					26,000	44,000	44,000	62,000	75,000	76,000	5
im.-tire cap.				32,000	50,000	50,000	60,000	60,000	NP	30,848	44,720	51,000	61,200	61,200	NP	6
pec. limits [13]		X		30,000	40,000	48,000	60,000	60,000	60,000	28,000	40,000	48,000	56,350	60,000	60,000	7
		X								30,000	46,000	52,000	58,450	61,490	64,650	8
			X							30,000	52,000	52,000	65,200	71,115	71,115	9
aximum [16]									63,280	28,340	48,680	48,680	63,290	63,280	63,280	10
[17]	700 & 800 (L+ 40)	Under 18'	Over 18'							32,000	38,800	56,000	62,800	69,600	78,000	11
		X								26,000	40,000	44,000	58,000	72,000	76,800	12
im.-tire cap.				36,000	[22]41,000	45,000	59,000	68,000	72,000	26,000	40,000	44,000	58,000	68,000	72,000	13
im.-tire cap. [23]									72,000	27,000	41,000	45,000	59,000	73,000	73,000	14
		X								26,540	40,960	45,080	59,500	58,657	NP	15
		X								26,000	40,000	44,000	55,470	63,890	63,890	16
im.-tire cap.[29]				36,000	50,000	54,000	59,640	59,640	NP	26,900	41,600	45,800	59,640	59,640	NP	17
m.-tire cap.										26,000	40,000	44,000	58,000	72,000	76,000	18
ire cap.		X		32,000	50,000	50,000	60,000	60,000	60,000	30,000	40,000	52,000	60,000	60,000	60,000	19
	850 (L+ 40)		X					65,000	65,000	30,400	48,000	52,800	65,000	65,000	65,000	20
pec. limits	1,000 (L+ 25)		X	[32]46,000	[32]60,000	[32]60,000	[32]60,000	[32]60,000	NP	30,400	44,000	52,800	60,000	60,000	NP	21
m.-tire cap.										26,000	[30]40,000	44,000	[35]58,000	[35]66,000	[35]102,000	22
		X								26,000	40,000	44,000	58,000	68,000	72,500	23
ire cap.		X								26,000	36,650	44,000	[35]54,650	[35]55,980	[35]55,980	24
		X								26,000	40,000	44,000	55,470	64,650	64,650	25
		Under 18'	Over 18'							26,000	40,000	44,000	58,000	72,000	76,000	26
		Under 22'	Over 22'							26,780	41,200	45,320	57,134	66,590	66,590	27
		Under 18'	Over 18'							26,900	41,600	45,800	60,000	74,000	76,800	28
spec. limits			X	33,400	[38]47,500	52,800	66,400			30,400	44,000	52,800	66,400	66,400	66,400	29
imits				30,000	40,000	60,000	60,000	60,000	60,000	31,500	41,600	55,040	63,000	63,000	63,000	30
		Under 18'	Over 18'							29,600	42,320	51,200	63,920	76,640	86,400	31
	34,000+ 850L		X					65,000	65,000	30,400	44,000	52,800	65,000	65,000	65,000	32
imits				31,500	46,200	46,200	58,800	58,800	58,800	27,000	46,000	46,000	58,800	58,800	58,800	33
	650 & 750 (L+ 40)	Under 18'	Over 18'							26,000	38,000	44,000	56,000	63,750	63,750	34
	800 (L+ 47.5)		X							27,000	39,500	46,000	58,500	71,000	78,000	35
		X								26,000	40,000	44,000	55,470	60,000	60,000	36
8		Under 18'	Over 18'					72,000	76,000	26,000	40,000	44,000	58,000	72,000	76,000	37
imits [49]				33,000	47,000	50,000	60,000	60,000	62,000	31,072	45,080	51,500	61,800	61,800	63,860	38
im.-tire cap.																39
imits				[50]36,000	[51]44,000	[52]50,000	[53]60,000	60,000	88,000	30,400	44,000	50,000	60,000	60,000	88,000	40
		X								28,000	40,000	48,000	60,000	66,839	71,115	41
		X								26,000	40,000	44,000	58,000	72,000	73,280	42
			X							26,000	40,000	44,000	55,980	55,980	43,500	43
		X								26,900	41,600	45,800	57,844	61,340	61,340	44
		X								26,000	41,000	44,000	59,000	74,000	79,900	45
im.-tire cap.				30,000	40,000	50,000	[55]60,000	[55]60,000	[55]60,000	30,000	40,000	50,000	60,000	60,000	60,000	46
		X						[35]56,800	[35]56,800	26,000	40,000	44,000	56,800	56,800	56,800	47
pec. lim.[59]		Under 18'	Over 18'	28,000	36,000	46,000	60,000	68,000	72,000	26,000	36,000	44,000	60,000	68,000	72,000	48
		X								26,900	41,600	45,800	57,844	63,840	63,840	49
ormula[61]	1,000 (L+ 26)	X								27,500	40,000	47,000	59,500	68,000	68,000	50
		X								26,000	44,000	44,000	62,000	73,000	73,000	51
	1.025 (L +24)-3L [2]	X								26,000	40,000	44,000	55,470	61,490	71,900	
a 6		18	19							29	25	29	45	35	20	
31										21	20	21	4	2	0	
ied limits 14										0	5	0	1	13	30	

inches.
Rural Roads Authority 56,000 pounds maximum.
when L is greater than 18': 900 (L+ 40) on highways having no

th at least 20 feet or otherwise as administratively authorized.

nd timber products, ores, concentrates, aggregates, and agri-
le 18,900 pounds, tandem axle 37,800 pounds, gross weight table:
s maximum at 21-foot axle spacing, vehicle with 5 or more axles
spacing.
er highways.

ounds, tandem axle 36,000 pounds; tolerance of 1,000 pounds on
e limitations of axle load and gross weight.

other highways.
buses 30 feet on other highways.
.

000 pounds; on Class B highways 30,000 pounds.

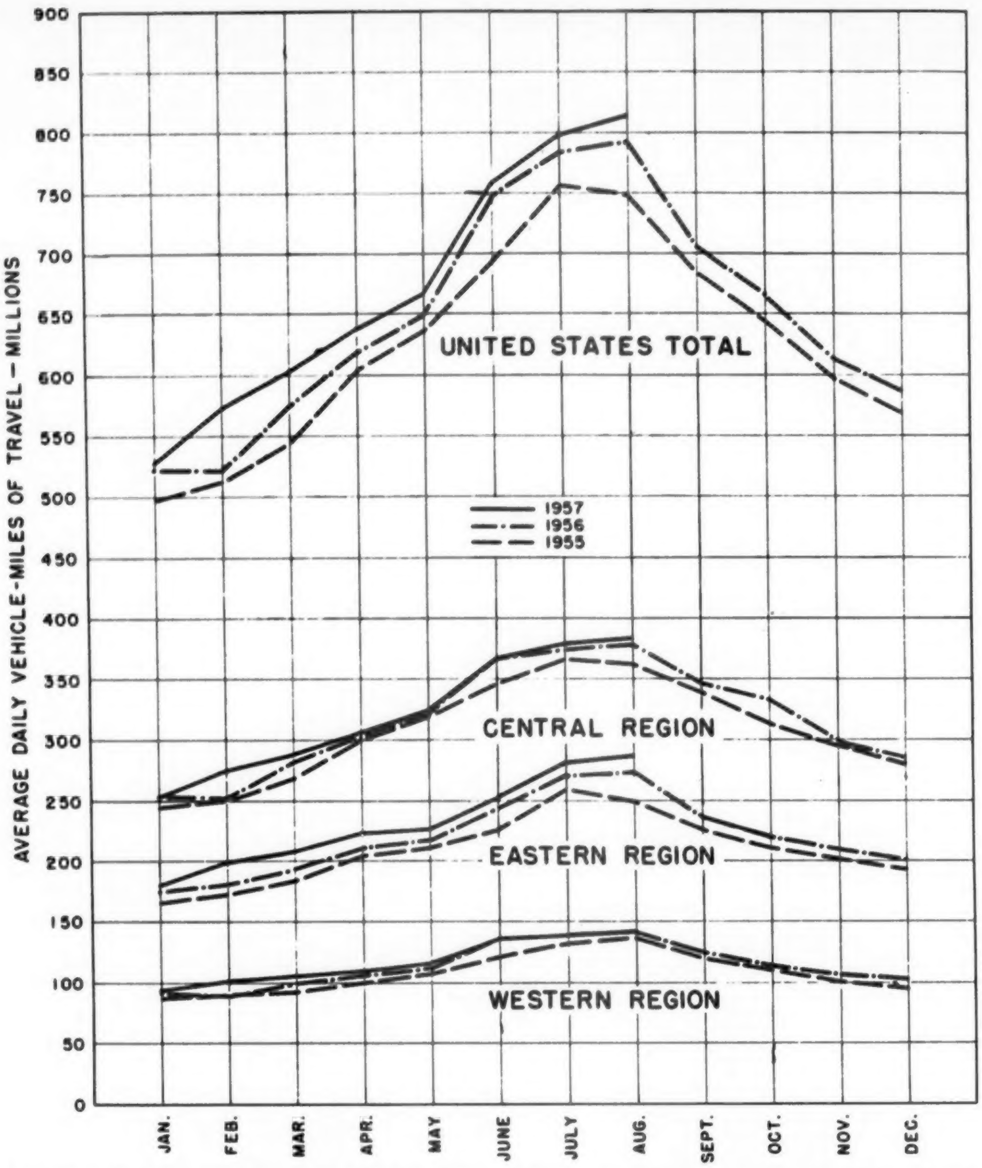
rest axle limited to 13,000 pounds.
ne tandem axle in combination; otherwise 26,000 pounds.

1 trailer by means of a dolly.

[39] Or as prescribed by P.U.C.
[40] Exception for poles, pilings, structural units, ec., permitted 70 feet.
[41] On designated highways 102 inches.
[42] Trackless trolleys and buses 7 passengers or more, P.S.C. certificate 40 feet.
[43] Including front and rear bumpers.
[44] Spaced less than 4 feet 24,000 pounds.
[45] Certain types of vehicles and commodities under special permit on designated highways up to 13 feet 6 inches.
[46] 60 feet allowed truck tractor semitrailer on 4 major Interstate routes.
[47] Logging vehicles permitted 3-foot wheelbase tolerance, 19,000-pound single axle, 34,000-pound tandem axle.
[48] Governs gross weight permitted on highways designated by resolution of State highway commission.
[49] Single unit truck with 4 axles permitted 60,000 pounds.
[50] Axles spaced less than 6 feet 32,000 pounds; less than 12 feet 36,000 pounds; 12 feet or more gross weight governed by axle limit.
[51] Single vehicle with 3 or more axles spaced less than 16 feet 40,000 pounds; less than 20 feet 44,000 pounds; 20 feet or more governed by axle limit.
[52] Tractor semitrailer with 3 or more axles spaced less than 22 feet 46,000 pounds; not less than 27 feet 50,000 pounds.
[53] Axles spaced 27 feet or more.
[54] Auto transports and vehicles transporting materials for Department of Defense on highways with adequate clearance 13' -6".
[55] Tandem axles on trailer equipped with adequate brakes.
[56] Vehicles registered before July 1, 1956, permitted limits in effect January 1, 1956, for life of vehicle.
[57] Under State highway commission rules.
[58] Within discretion of enforcement officer.
[59] Vehicles hauling logs permitted wheelbase and gross weight tolerances. Discretionary enforcement tolerances not included in computation of practical maximum gross weights.
[60] Axle load 21,000 pounds on 2-axle trucks hauling unmanufactured forest products.
[61] On Class A highways.
[62] Based on ruling of Attorney General.

Figure 3* (Right).—*Average daily travel on main rural roads in 1955, 1956, and in the first 8 months of 1957.

(Continued from page 255)



is as follows: eastern region, 220 and 209 million vehicle-miles; central region, 316 and 308 million vehicle-miles; and western region, 114 and 108 million vehicle-miles, respectively. Percentage increases in 1956 over 1955 for the three regions were 5.3 percent for the eastern, 2.6 percent for the central, and 5.6 percent for the western.

Table 3 provides a comparison of the estimated vehicle-miles of travel on main rural roads by 5-year periods from 1936 through 1956. From the data given in this table it is seen that the vehicle-mileages traveled by major classes of vehicles were approximately the same in 1946 as in 1941. However, during the war period single-unit truck travel decreased 6 percent, whereas travel by truck combinations increased 27 percent.

In the 5 years that followed 1946, traffic by all classes of vehicles increased faster than in any other similar period. The annual average growth rates were as follows: all vehicles, 10.4 percent; passenger cars and buses, 9.8 percent; all trucks and truck combinations, 13.2 percent; single-unit trucks, 11.2 percent; and truck combinations, 19 percent.

In the last 5-year period (1951–56), the average annual increases, although showing a steady gain, were generally much smaller than those of the previous 5-year periods. The annual growth rates were as follows: all vehicles, 5.0 percent; passenger cars and buses, 5.2 percent; trucks and truck combinations, 4.8 percent; single-unit trucks, 4.4 percent; and truck combinations, 5.4 percent.

Over the 20-year period, 1936–56, travel by all vehicles increased an average amount each year of 8.4 percent; passenger cars and buses, 7.8 percent; all trucks and combinations, 11.2 percent; single-unit trucks, 8.4 percent; and truck combinations, 24.4 percent.

A comparison of 1956 travel on main rural roads with 1955 data previously published reveals the following increases in 1956: all vehicles, 4.3 percent; passenger cars, 4.0 percent; all trucks and truck combinations, 5.5 percent; single-unit trucks, 5.2 percent; and truck combinations, 6.0 percent.

An interesting and important observation, as shown in table 3, is that the percentage of travel by combination vehicles, in relation to total truck travel, increased more rapidly in the 10-year period, 1936–46, than in the period, 1946–56. In 1936, about 18 percent of the travel of all freight-carrying vehicles was by combination types, while in 1946, the percentage had increased to approximately 27 percent. In 1951 and 1956, the percentages were 31 and 32, respectively.

Distribution of Traffic Within Census Divisions

The percentage distribution of travel, by vehicle types, on main rural roads within each census division is given in table 4. The table shows that the largest percentage of passenger-car travel in relation to total travel within a division was in the Pacific division, with the New England division following closely. A comparison of truck travel shows that the East South Central division has the highest percentage, with the West South Central and Mountain divisions following in order. The lowest percentages for truck travel were found in the Pacific and New

Table 3.—Comparison of estimated vehicle-miles of travel on main rural roads in 1936, 1941, 1946, 1951, and 1956

Year	Total travel, vehicle-miles	Passenger-car and bus travel		Truck and truck-combination travel		Single-unit truck travel		Truck-combination travel	
		Vehicle-miles	Percentage of total travel	Vehicle-miles	Percentage of total travel	Vehicle-miles	Percentage of total truck travel	Vehicle-miles	Percentage of total truck travel
	Millions	*Millions*		*Millions*		*Millions*		*Millions*	
1936	88,412	73,005	82.57	15,407	17.43	12,650	82.11	2,757	17.89
1941	122,721	98,509	80.27	24,212	19.73	19,067	78.75	5,145	21.25
1941:1936 ratio	*1.39*	*1.35*	*.97*	*1.57*	*1.13*	*1.51*	*1.96*	*1.87*	*1.19*
1946	124,373	99,985	80.39	24,388	19.61	17,850	73.19	6,538	26.81
1946:1941 ratio	*1.01*	*1.01*	*1.00*	*1.01*	*.99*	*.94*	*.93*	*1.27*	*1.26*
1946:1936 ratio	*1.41*	*1.37*	*.97*	*1.58*	*1.13*	*1.41*	*.89*	*2.37*	*1.50*
1951	189,650	149,109	78.62	40,541	21.38	27,810	68.60	12,731	31.40
1951:1946 ratio	*1.52*	*1.49*	*.98*	*1.66*	*1.09*	*1.56*	*.94*	*1.95*	*1.17*
1951:1941 ratio	*1.55*	*1.51*	*.98*	*1.67*	*1.08*	*1.46*	*.87*	*2.47*	*1.48*
1951:1936 ratio	*2.15*	*2.04*	*.95*	*2.63*	*1.23*	*2.20*	*.84*	*4.62*	*1.76*
1956	237,748	187,678	78.94	50,070	21.06	33,842	67.59	16,228	32.41
1956:1951 ratio	*1.25*	*1.26*	*1.00*	*1.24*	*.99*	*1.22*	*.99*	*1.27*	*1.03*
1956:1946 ratio	*1.91*	*1.88*	*.98*	*2.05*	*1.07*	*1.90*	*.92*	*2.48*	*1.21*
1956:1941 ratio	*1.94*	*1.91*	*.98*	*2.07*	*1.07*	*1.77*	*.86*	*3.15*	*1.53*
1956:1936 ratio	*2.69*	*2.57*	*.96*	*3.25*	*1.21*	*2.68*	*.82*	*5.89*	*1.81*

Table 4.—Percentage distribution of travel, by vehicle types for each census division, on main rural roads in the summer of 1956 with comparative data by vehicle types for 1951

Vehicle type	Eastern region: New England division	Eastern region: Middle Atlantic division	Eastern region: South Atlantic division	Eastern region: Average	Central region: East North Central division	Central region: East South Central division	Central region: West North Central division	Central region: West South Central division	Central region: Average	Western region: Mountain division	Western region: Pacific division	Western region: Average	United States average, 1956	United States average, 1951	1956:1951 ratio of vehicle-miles traveled
Passenger cars:															
Local	60.46	59.71	58.73	59.33	57.62	52.14	62.32	58.99	58.01	75.24	42.24	62.99	59.33	59.26	1.25
Foreign	22.23	17.28	20.37	19.54	22.09	19.38	17.67	14.59	18.87	32.91	8.41	17.50	18.86	18.43	1.28
All passenger cars	82.69	76.99	79.10	78.87	79.71	71.52	79.99	73.58	76.88	75.15	83.65	80.49	78.19	77.69	1.26
Single-unit trucks:															
Panel and pickup	3.57	8.72	7.41	7.31	5.21	9.68	6.00	11.35	7.64	10.16	7.30	8.36	7.66	7.00	1.37
Other 2-axle, 4-tire	2.64	1.37	.80	1.27	.19	.02	.35	.05	.16	1.06	.82	.91	.66	.62	1.35
Other 2-axle, 6-tire	5.25	5.19	5.32	5.27	5.49	8.07	5.67	5.61	5.98	6.53	1.83	3.58	5.32	6.62	1.01
3-axle	.60	.63	.72	.67	.57	.51	.50	.18	.46	.98	.73	.82	.59	.43	1.72
All single-unit trucks	12.06	15.91	14.25	14.52	11.46	18.28	12.52	17.19	14.24	18.73	10.68	13.67	14.23	14.67	1.22
Truck-tractor and semitrailer combinations:															
3-axle	3.59	4.30	1.84	2.97	2.50	3.53	1.94	2.77	2.62	1.49	.62	.94	2.44	3.52	.87
4-axle	.97	1.77	3.77	2.65	4.33	5.59	3.62	5.17	4.60	1.26	.61	.85	3.29	2.22	1.86
5-axle or more	.01	.02	.02	.02	1.00	.03	1.18	.50	.75	1.93	1.12	1.42	.62	.50	1.54
All truck-tractor and semitrailer combinations	4.57	6.09	5.63	5.64	7.83	9.15	6.74	8.44	7.97	4.68	2.35	3.21	6.35	6.24	1.27
Combinations involving full trailers:															
4-axle or less	.01	.27	.01	.10	.06	----------	.18	.05	.07	.20	.12	.15	.10	.14	.85
5-axle	----------	.01	.01	.01	.31	----------	.08	.01	.14	.53	1.84	1.36	.31	.21	1.87
6-axle or more	----------	----------	----------	----------	.10	----------	(1)	----------	.04	.04	.46	.30	.07	.12	.75
All combinations involving full trailers	.01	.28	.02	.11	.47	----------	.26	.06	.25	.77	2.42	1.81	.48	.47	1.27
All combinations	4.58	6.37	5.65	5.75	8.30	9.15	7.00	8.50	8.22	5.45	4.77	5.02	6.83	6.71	1.26
All trucks and combinations	16.64	22.28	19.90	20.27	19.76	27.43	19.52	25.69	22.46	24.18	15.45	18.69	21.06	21.38	1.24
Buses	.67	.73	1.00	.86	.53	1.05	.49	.73	.66	.67	.90	.82	.75	.93	1.01
All vehicles	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	1.25

[1] Less than 0.005 percent.

England divisions. This condition naturally follows the higher percentage of passenger-car travel in these two areas. On a percentage basis, travel by all types of truck combinations in the East South Central division exceeded all other divisions and was followed closely by the West South Central division. When the comparison is restricted to truck and full-trailer combinations, it can readily be seen that travel by this vehicle type is heavily concentrated in the Pacific division particularly, and also in the Mountain and East North Central divisions.

When the percentage distribution of travel by types of vehicles on main rural roads in 1956, as given in table 4, is compared with a similar distribution for 1951, it is found that during the 5-year period, passenger-car travel and truck-combination travel related to total travel increased slightly; while that of single-unit trucks decreased.

The ratios of 1956 traffic on main rural roads to corresponding traffic in 1951 for each type of vehicle is given in the right-hand column of table 4. For the United States as a whole, travel increased 25 percent in 1956 compared with 1951, an average annual increase of 5.0 percent. During the period, passenger-car travel increased at the rate of 5.2 percent a year; single-unit trucks, 4.4 percent; truck combinations, 5.2 percent; and buses, 0.2 percent.

Weight Stations Operated

During the summer of 1956 a total of 506 loadometer or pitscale stations were operated in 43 States for the purpose of collecting data concerning vehicle types, weights, and loading

Table 5.—Comparison of vehicle-miles of travel, percentage distribution of travel, percentage of vehicles loaded, average weight of loaded vehicles, percentage of vehicles empty, average weight of empty vehicles, and average weight of loaded and empty vehicles on main rural roads, by vehicle types, in 1956 and 1951

Vehicle type	Vehicle-miles of travel		Percentage of vehicle-miles traveled		Percentage loaded		Average weight of loaded vehicles		Percentage empty		Average weight of empty vehicles		Average weight of loaded and empty vehicles	
	1956	1951	1956	1951	1956	1951	1956	1951	1956	1951	1956	1951	1956	1951
	Millions	*Millions*	*Percent*	*Percent*	*Percent*	*Percent*	*Pounds*	*Pounds*	*Percent*	*Percent*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Single-unit trucks:														
Panel and pickup	18,208	13,281	36.37	32.76	42.83	38.95	5,307	5,498	57.17	61.05	4,196	4,210	4,672	4,712
Other 2-axle, 4-tire	1,582	1,176	3.16	2.90	59.10	54.59	6,565	6,522	40.90	45.41	5,078	4,924	5,958	5,796
Other 2-axle, 6-tire	12,653	12,541	25.27	30.94	60.74	57.99	14,466	14,060	39.26	42.01	8,589	8,137	12,159	11,572
3-axle	1,399	812	2.79	2.00	59.11	60.84	30,790	29,924	40.89	39.16	15,553	15,187	24,557	24,153
Total or average	33,842	27,810	67.59	68.60	50.96	48.84	10,678	11,024	49.04	51.16	5,936	5,937	8,353	8,421
Truck-tractor and semitrailer combinations:														
3-axle	5,816	6,684	11.61	16.49	65.91	66.70	32,561	33,894	34.09	33.30	18,477	17,918	27,760	28,574
4-axle	7,814	4,208	15.61	10.38	70.41	71.65	47,640	47,266	29.59	28.35	24,109	23,337	40,677	40,482
5-axle or more	1,472	955	2.94	2.35	77.99	75.71	60,517	60,455	22.01	24.29	29,396	29,504	53,664	52,937
Total or average	15,102	11,847	30.16	29.22	69.41	69.18	43,535	41,373	30.59	30.82	22,062	20,282	36,966	34,873
Truck and trailer combinations:														
4-axle or less	229	269	.46	.66	76.86	68.40	46,844	42,545	23.14	31.60	18,933	26,293	40,424	37,409
5-axle	727	389	1.45	.96	71.66	59.64	65,742	65,594	28.34	40.36	27,954	28,303	55,029	50,543
6-axle or more	170	226	.34	.56	68.24	70.35	71,924	65,899	31.76	29.65	33,722	31,039	59,718	55,563
Total or average	1,126	884	2.25	2.18	72.20	65.04	62,520	58,599	27.80	34.96	27,437	28,325	52,767	48,015
Total or average, all combinations	16,228	12,731	32.41	31.40	69.60	68.89	44,900	42,501	30.40	31.11	22,403	20,911	38,063	35,784
Total or average, all trucks and combinations	50,070	40,541	100.00	100.00	57.00	55.13	24,221	23,376	43.00	44.87	9,708	9,197	17,980	17,014

Table 6.—Comparison of estimated percentage of trucks loaded, average carried load, and ton-miles carried on main rural roads in 1936, 1941, 1946, 1951, and 1956

Year	All trucks and truck combinations			Single-unit trucks			Truck combinations		
	Percentage loaded	Average weight of carried load	Ton-miles carried	Percentage loaded	Average weight of carried load	Ton-miles carried	Percentage loaded	Average weight of carried load	Ton-miles carried
		Tons	*Millions*		*Tons*	*Millions*		*Tons*	*Millions*
1936	62.8	2.90	28,005	60.7	1.86	14,258	72.2	6.90	13,747
1941	66.7	3.64	58,853	65.4	2.29	28,505	71.6	8.24	30,348
1941:1936 ratio	*1.06*	*1.26*	*2.10*	*1.08*	*1.23*	*2.00*	*.99*	*1.19*	*2.21*
1946	51.7	4.84	61,084	46.4	2.31	19,117	66.2	9.70	41,967
1946:1941 ratio	*.78*	*1.33*	*1.04*	*.71*	*1.01*	*.67*	*.92*	*1.18*	*1.38*
1946:1936 ratio	*.82*	*1.67*	*2.18*	*.76*	*1.24*	*1.34*	*.92*	*1.41*	*3.05*
1951	55.1	5.66	126,402	48.8	2.31	31,396	68.9	10.83	95,006
1951:1946 ratio	*1.07*	*1.17*	*2.07*	*1.05*	*1.00*	*1.64*	*1.04*	*1.12*	*2.26*
1951:1941 ratio	*.83*	*1.55*	*2.15*	*.75*	*1.01*	*1.10*	*.96*	*1.31*	*3.13*
1951:1936 ratio	*.88*	*1.95*	*4.51*	*.80*	*1.24*	*2.20*	*.95*	*1.57*	*6.91*
1956	57.0	6.00	171,249	51.0	2.39	41,248	69.6	11.51	130,001
1956:1951 ratio	*1.03*	*1.06*	*1.35*	*1.05*	*1.03*	*1.31*	*1.01*	*1.06*	*1.37*
1956:1946 ratio	*1.10*	*1.24*	*2.80*	*1.10*	*1.03*	*2.16*	*1.05*	*1.19*	*3.10*
1956:1941 ratio	*.85*	*1.65*	*2.91*	*.78*	*1.04*	*1.45*	*.97*	*1.40*	*4.28*
1956:1936 ratio	*.91*	*2.07*	*6.11*	*.84*	*1.28*	*2.89*	*.96*	*1.67*	*9.46*

practices. During this survey all vehicles (passenger cars, single-unit trucks, truck combinations, and buses) were counted at these stations and freight-carrying vehicles were classified according to number of axles and tire equipment. Approximately 428,000 trucks and truck combinations passed the stations of which about 138,000 were weighed. A record was made of the type of vehicle, the weight of its axles, the spacing between axles, and whether the vehicle was loaded or empty.

The stations used in the 1956 survey were located at the same points as in former years, most of them being at sites operated in the original surveys in the 1936–40 period. From comparable data collected at these locations, trends in travel, loading practices, and carried loads were obtained, which when applied to earlier estimates derived from comprehensive surveys, gave current estimates of annual vehicle-miles traveled by loaded vehicles and the carried load. The product of these two factors is the ton-miles of carried load. Data concerning the frequency of overloading and of heavy axle and heavy gross-weight occurrence also were made available. The remaining tables and charts in this article have been calculated by means of these trends, or by combining the actual data gathered in the summer survey with vehicle-mileage data developed from trends.

Table 5 provides considerable information concerning the vehicle-miles of travel by types of freight-carrying vehicles on main rural roads in 1956 and comparative data for 1951; also included are the percentage of travel of each vehicle type to the total travel of all types of trucks and truck combinations, the percentage carrying loads, the percentage traveling empty, the average loaded weight, the average empty weight, and the average weight of loaded and empty vehicles.

From table 5, it is seen that 57 percent of all freight-carrying vehicles were loaded and weighed an average of 24,221 pounds; empty vehicles averaged 9,708 pounds; and the average of all vehicles, loaded and empty, was 17,980 pounds. Data for 1956, when compared with those for 1951, show that the weights of loaded single-unit trucks decreased 3.2 percent in the 5-year period; truck combinations increased 5.6 percent; and the weights of all loaded vehicles increased 3.6 percent. At the same time, the weights of all empty single-unit trucks remained approximately the same; empty truck combinations increased 7.1 percent; and the weights of all empty vehicles, trucks and truck combinations, increased 5.6 percent. The average empty weights of truck and trailer combinations with four or less axles show a substantial decline from 1951 to 1956. The increasing use of homemade farm trailers drawn by lightweight trucks and similar combinations accounts for most of the decrease.

The heaviest average weights of loaded single-unit trucks in 1956 were found in the New England division, with those in the South Atlantic division being slightly less. Weights of loaded truck combinations were found to be heaviest in the Pacific division with those in the Mountain division being slightly smaller. The heaviest average weights for loaded trucks and truck combinations of all types were recorded in the East North Central division, with the average in the Pacific and Mountain divisions slightly lower. At the other extreme, the lowest average

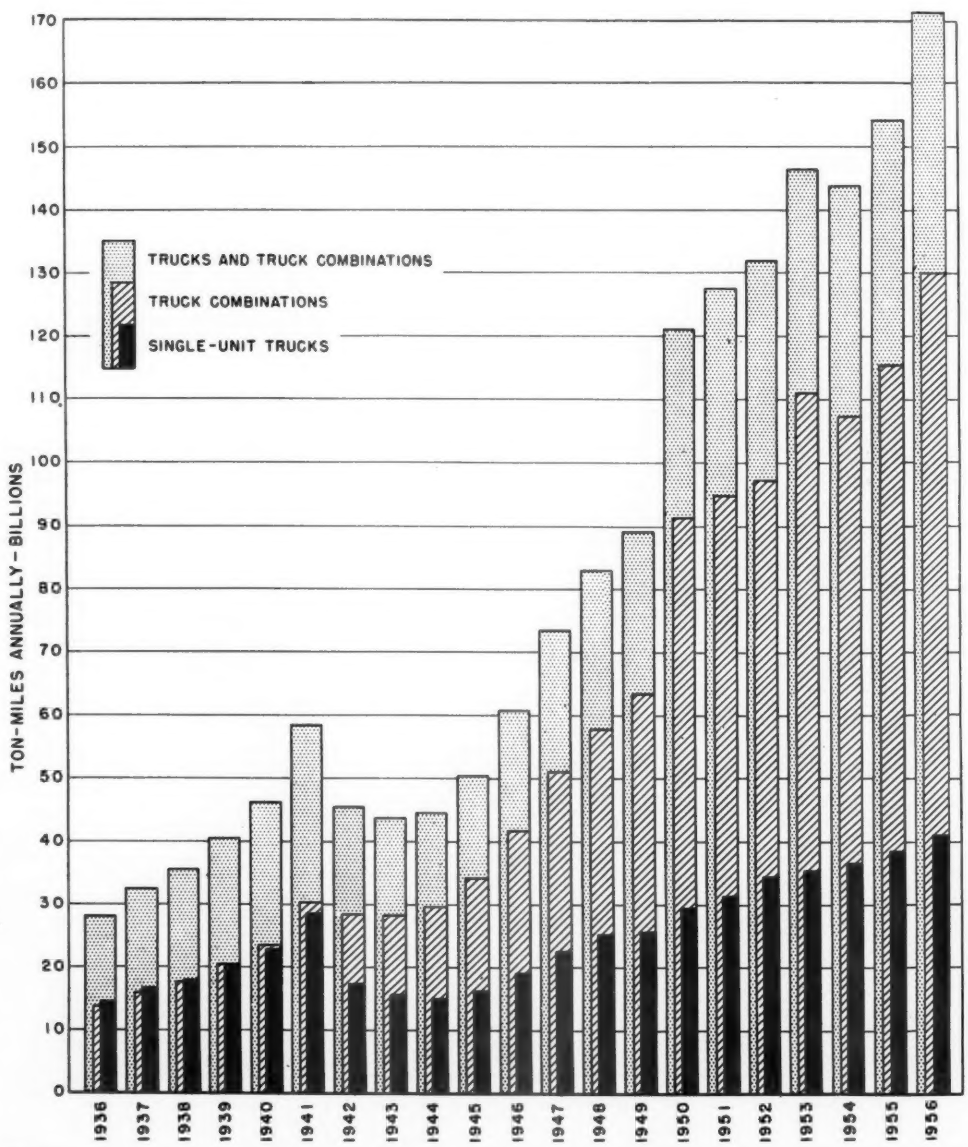


Figure 4.—Ton-miles carried by trucks and truck combinations on main rural roads, 1936–56.

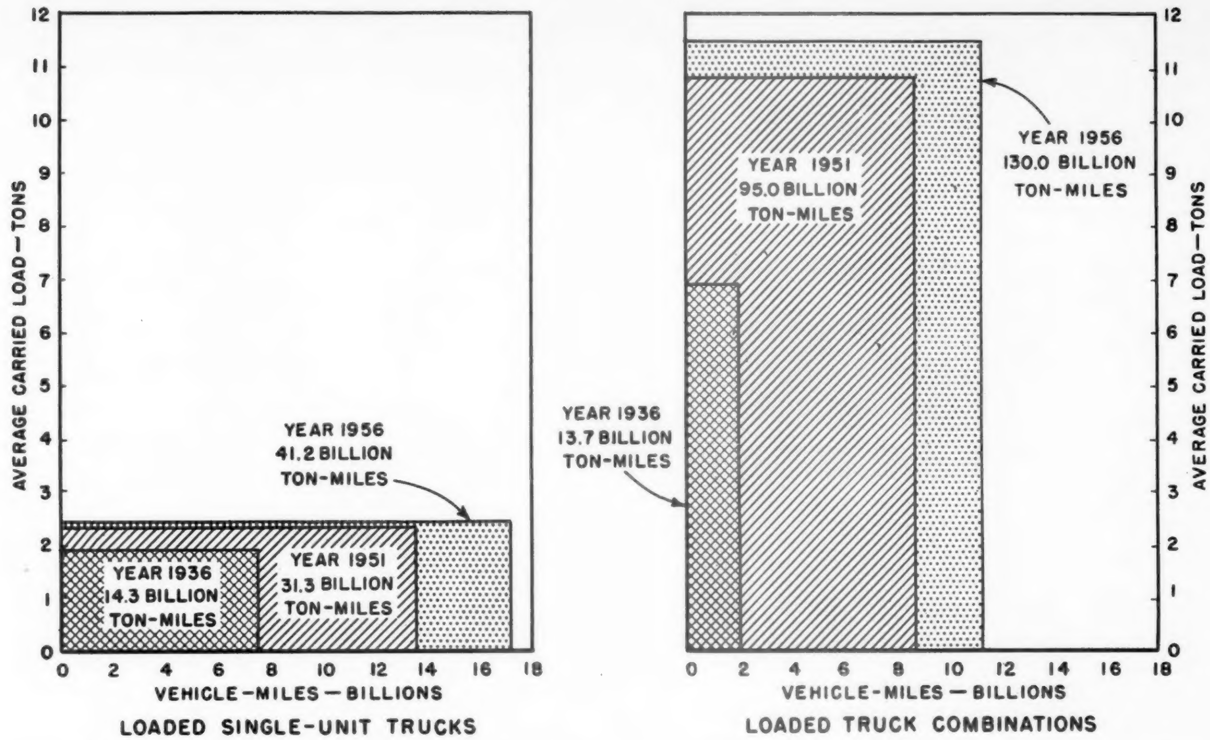


Figure 5.—Vehicle-miles of travel, average carried load, and ton-miles carried by trucks and truck combinations on main rural roads in 1956 compared with 1936 and 1951.

weights for all types of loaded vehicles were observed in the New England division. Average empty weights of vehicles followed an area distribution pattern similar to that for the average loaded weights.

Travel by Loaded Trucks Increases

The percentage of vehicles carrying loads has changed considerably since the beginning of the planning surveys, as indicated in table 6. From 1936 to 1941, between 60 and 65 percent of the single-unit trucks were loaded. When war was declared and driving restrictions were imposed, many small truck owners found it advantageous to use their vehicles for general transportation purposes. Thus it soon developed that the lighter weight trucks were being used more frequently for personal transportation than had previously been the case.

During World War II, the larger as well as the smaller single-unit trucks were used for the transportation of goods on less than half of their travel. Following the war, the popularity of the lightweight vehicles as a means of personal transportation continued, and in 1946 only about 46 percent of the travel of single-unit trucks involved carrying a load. Since 1946 the load factor has increased, and in 1956, for the first time since 1941, travel by loaded single-unit trucks exceeded that of empty vehicles of this type by a small margin.

For truck combinations, the relation of travel between loaded and empty vehicles has been fairly uniform throughout the 20-year period. In 1936 and 1941, 72 percent of the travel by these vehicles involved the carrying of goods or commodities as compared with 66 percent in 1946, 69 percent in 1951, and almost 70 percent in 1956. These comparisons may be noted more particularly in table 6 which gives, among other data, the percentages of loaded vehicles of the main freight-carrying types by 5-year periods commencing in 1936 and continuing through 1956.

Considering each type of truck and truck combination shown in table 5, it may be stated that the percentage that any type is

Table 7.—Comparison of percentage of travel by loaded vehicles, average carried load, relation of load to total loaded weight, ton-miles of carried load, and percentage of ton-miles carried, by vehicle types, in 1956 and 1951

Vehicle type	Percentage of travel by loaded vehicles		Average carried load		Relation of carried load to total loaded weight		Ton-miles of carried load		Percentage of ton-miles carried	
	1956	1951	1956	1951	1956	1951	1956	1951	1956	1951
Single-unit trucks:	*Percent*	*Percent*	*Tons*	*Tons*	*Percent*	*Percent*	*Millions*	*Millions*	*Percent*	*Percent*
Panel and pickup	27.32	23.14	0.75	0.70	28.3	25.5	5,882	3,611	3.44	2.86
Other 2-axle, 4-tire	3.28	2.87	1.08	.91	32.9	27.9	1,011	584	.59	.46
Other 2-axle, 6-tire	26.93	32.54	3.50	3.23	48.4	45.9	26,907	23,478	15.71	18.57
3-axle	2.90	2.21	9.01	7.54	58.5	50.4	7,448	3,723	4.35	2.95
Total or average	60.43	60.76	2.39	2.31	44.8	41.9	41,248	31,396	24.09	24.84
Truck-tractor and semitrailer combinations:										
3-axle	13.43	19.94	7.38	8.30	46.0	48.9	28,275	37,002	16.51	29.27
4-axle	19.27	13.49	12.32	12.42	52.6	52.5	67,799	37,460	39.59	29.64
5-axle or more	4.02	3.24	16.30	16.07	54.7	53.1	18,718	11,619	10.93	9.19
Total or average	36.72	36.67	10.95	10.50	51.1	50.7	114,792	86,081	67.03	68.10
Truck and trailer combinations:										
4-axle or less	.62	.82	14.63	8.45	55.0	40.5	2,575	1,554	1.50	1.23
5-axle	1.82	1.04	19.79	19.36	53.3	60.2	10,313	4,492	6.02	3.55
6-axle or more	.41	.71	20.01	18.10	49.1	56.0	2,321	2,879	1.36	2.28
Total or average	2.85	2.57	18.71	15.52	52.9	54.0	15,209	8,925	8.88	7.06
Total or average, all combinations	39.57	39.24	11.51	10.83	51.3	51.0	130,001	95,006	75.91	75.16
Total or average, all trucks and combinations	100.00	100.00	6.00	5.66	49.5	48.4	171,249	126,402	100.00	100.00

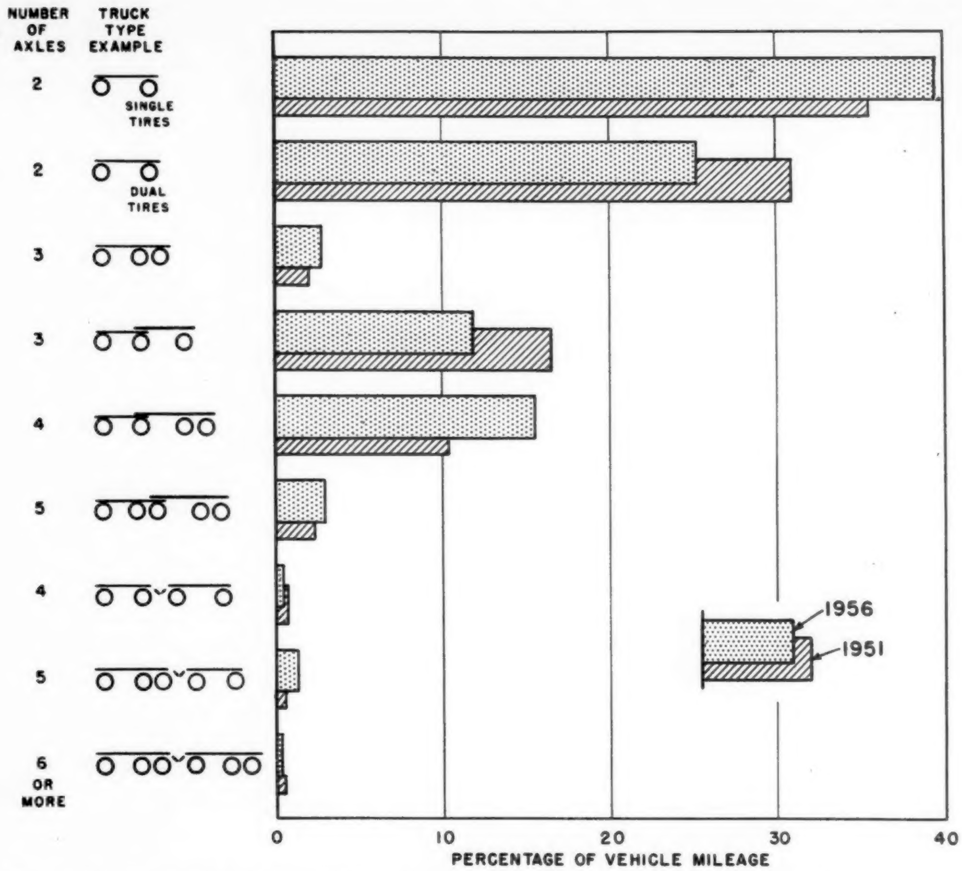


Figure 6.—Percentage of vehicle-miles traveled by various types of trucks and truck combinations on main rural roads in 1956 compared with 1951.

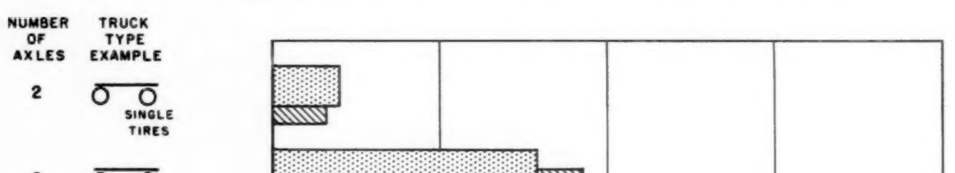


Figure 7.—Percentage of ton-miles hauled by various types of trucks and truck combinations on main rural roads in 1956 compared with 1951.

operated with a load increases roughly as the average weight increases. For instance, the 2-axle, 6-tire single-unit trucks, which averaged about 14,500 pounds loaded in 1956, were operated with a load about 61 percent of the time; the 3-axle tractor-semitrailer combinations, weighing over 32,500 pounds loaded, were operated with a load 66 percent of the time; and 4- and 5-axle combinations, weighing about 47,600 pounds and 60,500 pounds, were loaded 70 and 78 percent of the time, respectively.

Although the light panel and pickup trucks are used to a considerable extent for personal transportation, the slightly larger 2-axle trucks with single rear tires and carrying loads averaging about three-quarters of a ton were loaded 59 percent of the time, and surveys indicate little use for personal transportation. The same is true of the larger single-unit vehicles. Many of the truck combinations are common carriers which are less likely to be operated empty, inasmuch as they continually pick up and discharge freight. Combinations are found loaded in even greater proportion than the large single-unit trucks. Many of the latter type carry loads of a one-way variety, however, such as hauling building materials to construction projects, which tends to reduce the percentage loaded.

The variation in the percentage loaded of the several vehicle types, light and heavy, has an important effect on the distribution of vehicle-miles traveled by loaded vehicles and consequently on the ton-mileage of loads transported. A comparison of the percentages of vehicle-miles traveled by each vehicle type, as given in table 5, with the percentages of travel by each type of loaded vehicle, given in table 7, illustrates the wide differences between the total travel of these vehicles and the mileage of each when carrying a load.

Other interesting and useful information is given in table 7 concerning the average load in tons carried by each vehicle type and the relation in percentage points of the carried load to total loaded weight. From these data it may be observed that the average carried load and the relation of carried load to total load have generally increased in the 5-year period from 1951 through 1956. For instance, the tonnage carried by all types of tractor-semitrailer combinations increased from 10.50 tons in 1951 to 10.95 tons in 1956, while the relation of carried load to total weight increased from 50.7 percent in the earlier year to 51.1 percent in 1956. These increases, while small, indicate that larger payloads generally are being carried.

Volume of Freight Hauled

Ton-miles is the product of travel in vehicle-miles and the carried load in tons. The ton-mileages for each vehicle type traveling on main rural roads in 1956 and 1951 are given in table 7 with the corresponding percentage distribution.

Many interesting comparisons may be made from the data given in tables 5 and 7. For instance, 2-axle, 6-tire trucks, which are the principal load-carrying single-unit vehicles and which accounted for about 25 percent of

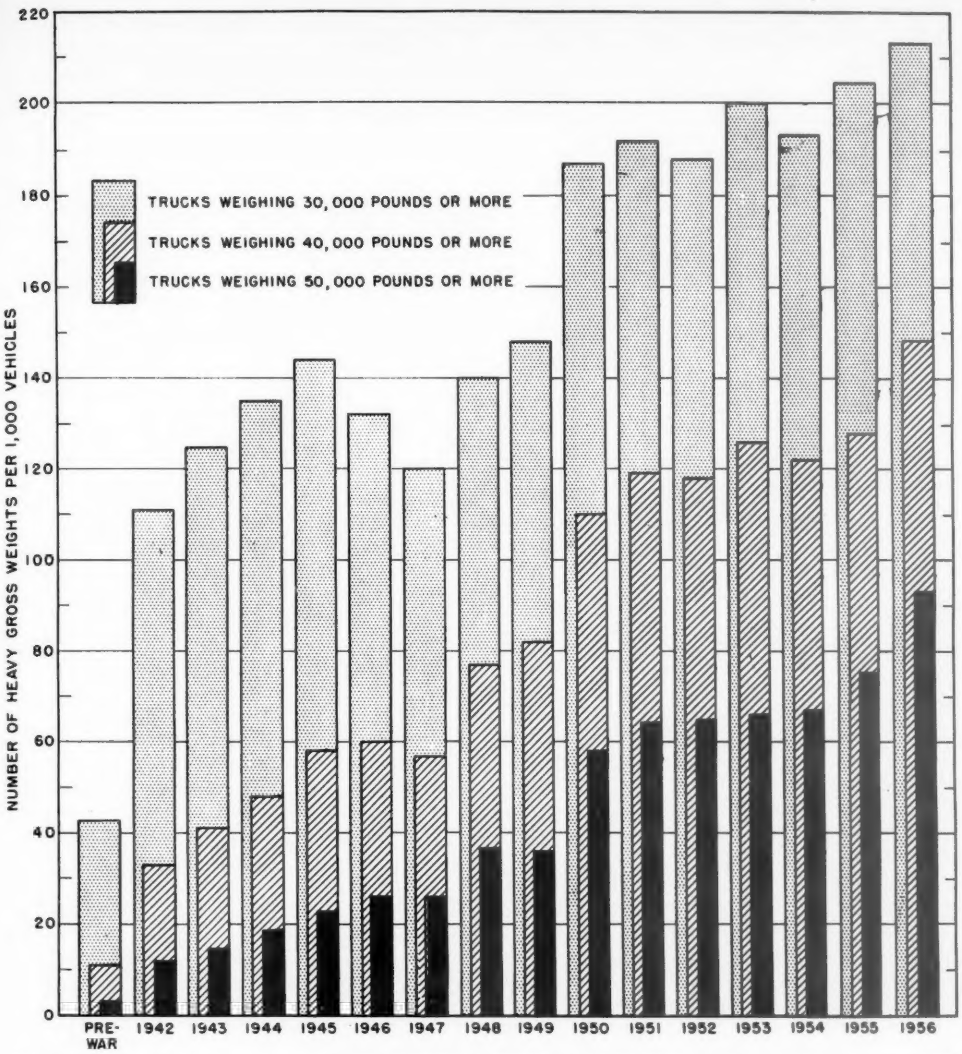


Figure 8.—Number of gross loads of 30,000, 40,000, and 50,000 pounds or more, per 1,000 loaded and empty trucks and truck combinations, on main rural roads in the summers of 1942-56 and a prewar year.

the total truck travel in 1956, carried less than 16 percent of the ton-mileage in that year. On the other hand, 4-axle tractor-semitrailer combinations, an increasingly popular vehicle among truckers, accounted for less than 16 percent of the total truck travel (about two-thirds as much as the 2-axle, 6-tire trucks), but carried almost 40 percent of the ton-mileage or 2½ times the percentage carried by the smaller vehicles.

The actual volume of freight carried annually from 1936 to 1956, inclusive, by trucks and truck combinations on main rural roads is shown in figure 4. The chart illustrates the tremendous growth in ton-miles of freight transported by truck combinations since the beginning of the planning surveys. In 1936, an estimated 13.7 billion ton-miles were transported by combination-type vehicles and slightly less than 14.3 billion ton-miles were transported by single-unit trucks. By 1940, the combination vehicles were hauling slightly more than the single-unit trucks, and in 1956, the ton-mileage hauled by combinations was more than three times that hauled by single-unit trucks.

The growth in ton-mileage by single-unit trucks and truck combinations from 1936 to 1956 is illustrated in another manner in figure 5. This chart shows the changes that have taken place in each of the two factors included in a ton mile. The horizontal scale measures the vehicle-mileage for loaded vehicles of each type, and the vertical scale measures the average carried load. Ton-mileage, the product of these two factors, is represented by the areas of the rectangles.

For single-unit trucks, the increase in ton-mileage from 14.3 billion in 1936 to 41.2 billion in 1956 came about mainly through an increase in the mileage traveled by loaded vehicles, since there was very little increase in the average carried load for this class of vehicle especially from 1951 to 1956. For truck combinations, the increase in ton-mileage from 13.7 billion in 1936 to 130.0 billion in 1956 was the result of a substantial increase in the average carried load and a much greater proportional increase in mileage traveled by loaded vehicles.

A comparison of the estimated percentage of trucks loaded, average carried load, and ton-miles of freight carried on main rural roads in 1936, 1941, 1946, 1951, and 1956 is given separately for single-unit trucks and truck combinations in table 6. The table shows the extent to which the ton-mileage gains were due to increased loading per vehicle. The increases beyond this point resulted from increased travel by loaded vehicles.

In considering the 1956:1936 ratios shown as the final entry of the table, it is observed that the ton-mileage for combinations was almost 10 times as great at the end of this 20-year period as it was at the beginning, while the ratios for the average weight of carried load and the percentage of vehicles loaded were 1.67 and 0.96, respectively. As shown in table 3, the corresponding ratio for the mileage traveled by all vehicles of the combination type, both loaded and empty, was 5.89, and when multiplied by 0.96, the ratio becomes 5.65 for loaded vehicles. Obviously, most of the enormous increase in ton-mileage was due to increased vehicle-mileage rather than to heavier loading, although loading increased 167 percent during the 20-year period.

For single-unit trucks, the percentage of vehicles loaded decreased 16 percent and the average load increased 28 percent during the period 1936–56. The 189 percent increase in ton-mileage for single-unit trucks was therefore only about 13 percent higher than the 168 percent increase in vehicle-mileage, as shown by the ratio in table 3.

The percentage of vehicle-mileage traveled by trucks of various types in 1956 compared with 1951 is shown in figure 6. The trucking industry in recent years has favored the 2-axle truck-tractor with dual-axle semitrailer over other combination types. This was not the case in 1951, when 16.5 percent of all truck travel was performed by 2-axle truck-tractors with single-axle semitrailers, as compared with 10.4 percent by the same type of tractor with dual-axle semitrailers. In 1956, 15.6 percent of all truck travel was by 2-axle truck-tractors with dual-axle semitrailers, whereas the same power unit with single-axle semitrailer accounted for 11.6 percent of the travel. A small increase in travel by 3-axle tractors pulling dual-axle semitrailers likewise may be noted during the period, 1951–56. The shift from 1- to 2-axle semitrailers apparently has taken place in order that maximum possible payloads can be carried under the weight restrictions in effect in the different States.

The percentage of ton-miles hauled by various truck types in 1956 compared with 1951 is shown in figure 7. This chart emphasizes, even more than figure 6, the shift that occurred between 1951 and 1956 from 3-axle tractor-semitrailer combinations to 4- and 5-axle combinations, as measured by the freight carried. In 1956, the 4-axle combinations accounted for more than two and one-third times the ton-mileage carried by the 3-axle combination type, whereas in 1951 the two types carried about the same amount.

Heavy Gross-Load Frequencies Increase

The frequencies of gross loads of 30,000, 40,000, and 50,000 pounds or more, per 1,000 trucks and truck combinations, on main rural roads in the summers of 1942 to 1956, and in a prewar period (1936–37) are shown in figure 8. During this period the trend of the fre-

Table 8.—Frequency of heavy vehicles of 30,000, 40,000, and 50,000 pounds or more, per 1,000 loaded and empty trucks and truck combinations, on main rural roads in the summer of 1956 by main vehicle types

Vehicle type	Number of vehicles, per 1,000 trucks and truck combinations, weighing—		
	30,000 pounds or more	40,000 pounds or more	50,000 pounds or more
Single-unit trucks:			
2-axle, 6-tire	4	(1)	(1)
3-axle	340	104	16
Average	16	4	1
Truck combinations:			
Truck-tractor and semitrailer	618	438	266
Truck and trailer	716	585	531
Average	625	448	285
Average, all trucks and combinations, 1956	213	148	93
Comparative average, 1955	205	128	75
Comparative average, 1954	193	122	67
Comparative average, 1951	192	119	64
Comparative average, 1946	132	60	26
Comparative average, 1936	43	11	3

[1] Less than 5 per 10,000.

quency of vehicles weighing 50,000 pounds or more was usually upward although at a generally lower rate of increase from 1951 to 1954. The frequency of those weighing 40,000 pounds or more was generally upward with temporary drops in 1947, 1952, and 1954. The long-range trend in frequency of weights of 30,000 pounds or more was also upward, but there was a substantial decline from 1945 to 1947 and temporary declines in 1952 and 1954.

From 1950 to 1954, the frequencies of weights of 30,000 and 40,000 pounds or more have fluctuated, but since 1954 there has been a decided upward trend. The percentage increases in 1956 over 1955 for the 30,000-, 40,000-, and 50,000-pound gross-weight groups were 4, 16, and 24 percent, respectively.

The 1956 gross-weight frequency data, by vehicle types, are presented in table 8. Since no panel and pickups or other 2-axle, 4-tire, single-unit trucks were found in the survey weighing as much as 30,000 pounds, there is no entry for these vehicles in the table. They are included, however, in the total number of vehicles weighed in computing the frequency for all single-unit trucks and for all trucks and combinations.

Table 8 shows that the frequency of heavy vehicles is steadily increasing. In the last 5 years the frequency of vehicles weighing 30,000 pounds or more increased 11 percent, vehicles weighing 40,000 pounds or more increased 24 percent, and those weighing 50,000 pounds or more increased 45 percent. In the last 10 years the increases were 61, 147, and 258 percent, respectively.

Combining the increases in the frequencies of heavy vehicles with the increases in travel by trucks and truck combinations, the mileage traveled in 1956 compared with 1951 by vehicles weighing 30,000, 40,000, and 50,000 pounds or more increased 38, 54, and 80 percent, respectively.

In addition to the gross-weight frequencies of vehicles traveling on main rural roads of the United States, the variation of these frequencies among the several geographical divisions is interesting. The highest frequency in 1956 of vehicles weighing 30,000 pounds or more (264) was found in the East North Central division, with the Pacific division (241) having the second highest frequency. The lowest frequency (176) was in the New England division. Similarly the highest frequency of vehicles weighing 40,000 pounds or more (186) was found in the Pacific division, with the second highest frequency (180) in the East North Central division. At the same time, the highest frequency of vehicles weighing 50,000 pounds or more (163) was found in the Pacific division, with the second highest frequency (112) in the East North Central division. The lowest frequency for this group (56) was found in the New England division. Considering the three weight groups, the frequencies of all heavy loads were greatest in the Pacific division with the East North Central division following closely. On the other hand, the smallest frequencies of such heavy loads were found generally in the New England division.

Heavy Axle-Load Frequencies Gain

The number of axles carrying loads of 18,000, 20,000, and 22,000 pounds or more, per 1,000 trucks and truck combinations, on main rural roads during the period 1942–56, and a prewar year are shown in figure 9. A most important finding indicated in the chart is the reversal in trends that took place in 1951 and 1955. In the first case an upward trend changed to a downward one, and in the second case a second upward trend occurred in all three weight groups. The 1956 frequencies show increases over 1954 and 1955 for each of the three weight groups, and in the case of 18,000- and 22,000-pound axle loads, the 1956 frequencies exceeded those of 1952, while the frequencies of loads weighing 20,000 pounds or more exceeded those of 1953.

The number of axles weighing 18,000 pounds or more in 1950 was more than seven times that in the prewar year, but from the 1950 high there was a drop of 34 percent by 1954.

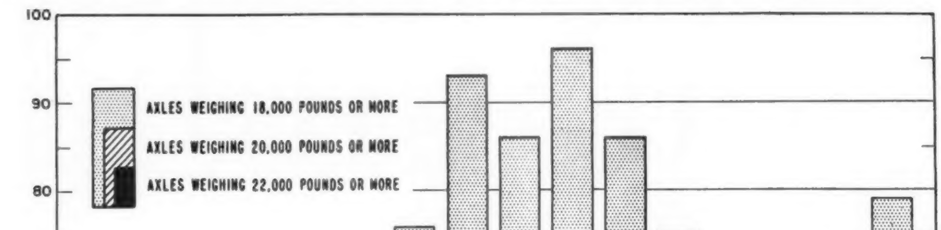


Figure 9.—Number of axles weighing 18,000, 20,000, and 22,000 pounds or more, per 1,000 trucks and truck combinations, on main rural roads in the summers of 1942–56 and a prewar year.

Table 9.—Frequency of axle loads of 18,000, 20,000, and 22,000 pounds or more, per 1,000 loaded and empty trucks and truck combinations, on main rural roads in the summer of 1956 by main vehicle types

Vehicle type	Number of axles, per 1,000 trucks and truck combinations, weighing—		
	18,000 pounds or more	20,000 pounds or more	22,000 pounds or more
Single-unit trucks:			
2-axle, 6-tire	35	12	4
3-axle	95	54	31
Average	17	7	3
Truck combinations:			
Truck-tractor and semitrailer	214	80	33
Truck and trailer	135	17	7
Average	209	76	31
Average, all trucks and combinations, 1956	79	29	12
Comparative average, 1955	73	26	10
Comparative average, 1954	64	20	8
Comparative average, 1951	86	34	14
Comparative average, 1946	68	26	10
Comparative average, 1936	13	5	2

Since 1954, the new upward trend has increased the frequency of this axle-weight group by 23 percent. Likewise, the frequency of 20,000-pound axles in 1950 was almost eight times that in the prewar year, but by 1954 the number in this category was almost one-half of that in 1950. In 1956, the frequency of 20,000-pound loads had increased 45 percent above the 1954 level. The number of axle loads of 22,000 pounds or more increased ninefold from the prewar year to 1950 but dropped 56 percent below that peak in 1954. As in the case of the two lower weight groups, there has been a marked upward trend in 1955 and 1956 for the heaviest axle loads—a 50-percent increase since 1954.

The number of axles weighing 18,000, 20,000, and 22,000 pounds or more for each 1,000 loaded and empty trucks and truck combinations in 1956 are given in table 9 for the main vehicle types. Comparative data are also given for 1955, 1954, 1951, 1946, and 1936. Since none of the 2-axle, single-unit trucks with single rear tires were found to have axles weighing as much as 18,000 pounds, that type is not shown in the table. The number of such vehicles counted are included, however, in obtaining the total frequencies for all single-unit trucks and for all trucks and combinations.

The downward trend in frequencies of heavy axle loads that began in 1950 and extended to 1954 was caused apparently by the shift to vehicles with a larger number of axles. By shifting to tractors and semitrailers with dual axles, truckers are able to haul heavier loads over the highways and yet subject them to less frequent applications of heavy axle loads.

Counteracting the good effects of the shift to vehicles with multiple axles, the increased axle-weight limits, which have been adopted in some States, and the tolerances that have been allowed in many, have made it possible for truckers to increase their payloads without violating the weight laws as they are enforced. These liberalized weight limits apparently are responsible for the increase in frequencies that have occurred in 1955 and 1956.

In order to give a clearer indication of what is happening on the roads, travel by vehicles with axles weighing 18,000, 20,000, and 22,000 pounds or more was calculated in vehicle-miles for the period 1950–56. These calculations show that when vehicle-mileage trends are included, there was an overall upward trend of about 3 percent in axles weighing 18,000 pounds or more, while the travel of vehicles with axles weighing 20,000 and 22,000 pounds or more decreased 7 and 16 percent, respectively. Since axle-load frequencies reached an all-time high in 1950, the above comparisons are made with that year.

Loads Exceeding Legal Limits

The number of trucks and truck combinations in 1956, per 1,000 loaded and empty vehicles, that exceeded the axle, axle-group, or gross-weight limits in effect in the States or recommended by the AASHO, with comparative figures for 1951, are given in table 10. The 1956 frequencies of overloads, especially those including lower percentages of overloads, generally exceeded those for 1951. The 1956 frequencies likewise are somewhat higher than those of the previous year.

This comparison is similar to the variations in heavy axle-load and heavy gross-load frequencies found in the years from 1950 through 1956 as shown in figures 8 and 9. These increased frequencies, which exceed the legal weight limits by small amounts, such as up to 10 percent, are caused in many cases by the tolerances in weight limits (generally 5 percent overloads) that now are being allowed in many States. It appears that in many cases these tolerances are being used as a license to increase the axle-load limit by the amount of the tolerance.

Detailed estimates concerning the overload frequencies in the various geographical areas show that the highest frequency of loads in excess of State legal weight limits in 1956 was

(Continued on page 267)

Table 10.—Number of trucks and truck combinations, per 1,000 loaded and empty vehicles, that exceeded any of the axle, axle-group, or gross-weight limits in effect in the States or recommended by the AASHO, in the summer of 1956 and the corresponding comparative figures in 1951

Vehicle type	Vehicles exceeding State legal limits						Vehicles exceeding AASHO recommendations					
	Number per 1,000 overloaded	Number per 1,000 overloaded more than—					Number per 1,000 overloaded	Number per 1,000 overloaded more than—				
		5 percent	10 percent	20 percent	30 percent	50 percent		5 percent	10 percent	20 percent	30 percent	50 percent
VEHICLES OVER LIMITS IN 1956												
2-axle, 6-tire truck	18	9	4	2	1	(1)	30	10	12	5	2	1
3-axle truck	80	49	26	11	5	3	109	71	42	24	13	6
Average, single-unit trucks	10	5	3	1	(1)	(1)	16	10	6	3	1	(1)
Truck-tractor and semitrailer	145	88	48	15	4	1	230	168	111	46	17	3
Truck and trailer	249	83	37	12	6	1	508	369	220	57	25	11
Average, truck combinations	152	87	48	15	5	1	249	182	119	47	17	3
Average, all trucks and combinations	56	32	17	6	2	(1)	91	66	43	17	6	1
VEHICLES OVER LIMITS IN 1951												
2-axle, 6-tire truck	15	10	7	3	2	(1)	21	17	13	7	4	1
3-axle truck	71	46	19	6	3	1	83	57	35	12	5	1
Average, single-unit trucks	9	6	4	2	1	(1)	12	9	7	4	2	(1)
Truck-tractor and semitrailer	139	89	52	20	7	1	198	142	94	40	17	3
Truck and trailer	157	78	32	7	1	(1)	282	211	139	54	10	2
Average, truck combinations	140	88	51	19	7	1	204	147	97	41	17	3
Average, all trucks and combinations	50	32	19	7	3	(1)	72	52	35	16	7	1

[1] Less than 5 per 10,000.

How Access Control Affects Accident Experience

BY THE DIVISION OF HIGHWAY TRANSPORT RESEARCH
BUREAU OF PUBLIC ROADS

Reported by CHARLES W. PRISK,
Director, Highway Safety Study

NEW EVIDENCE has been developed to document the striking safety benefits in the offing for users of the National System of Interstate and Defense Highways now under construction. Full control of access is the key feature in the outlook for safer travel.

Control of access is sometimes regarded as a relatively recent highway refinement. In many ways, however, nearly all of the important design advancements that have gradually evolved to make our highways safer serve also to control access. The grade separation of intersecting highways, for example, is control of access to the extent that the conflicts created by entering and leaving vehicles are eliminated through design of the separation structure and its connecting ramps for interchange traffic. Similarly, the physical division of a highway with a median area introduces access control of a degree because it prohibits or at the very least discourages left-turn access to abutting property.

A few years ago the Bureau of Public Roads invited the cooperation of the State highway departments in a survey of accident experience on controlled access routes. This effort, still continuing, has produced some convincing facts concerning the superior safety associated with control of access.

In most instances, data were obtained for pairs of routes or for abutting sections of highway serving the same general area—one highway with full or partial control of access, and the other a conventional major traffic route without access control. The access control concepts and nomenclature follow the standard definitions approved by the American Association of State Highway Officials. In other words, "full control of access" means that access is provided with selected public roads only and that crossings at grade and direct private driveway connections are prohibited. Where the term "partial control of access" is mentioned, the highway is of a somewhat lower order, and may have some crossings at grade and some private driveway connections.

Table 1 presents the Bureau's most recent compilation of accident experience on highways with full, partial, and no control of access, and was prepared from special reports from 27 States. These data include a total of 47,000 accidents, 30,000 injuries, and nearly 900 deaths occurring on 2,093 miles of highway study sections, and were assembled from records for various years, 1949 through 1955.

Freeways Are Safer

As the mileage figures indicate, composite results are preponderantly weighted by rural sections where fatality rates are commonly higher, and accident rates lower than in urbanized areas. However, for the aggregate experience, drivers on highways with fully planned access are roughly two and one-half times safer from fatalities, injuries, and accidents on a miles-traveled basis than their companions on comparable highways without access control.

The safety characteristics of the fully controlled access highway, which in standard nomenclature is better known as a freeway, are outstanding in the category of rural area fatalities. For example, as table 1 shows, the fatality rate on rural freeways is only one-third that of rural highways without access control, 3.4 deaths per 100 million vehicle-miles in contrast with an average of 10.3 deaths. This finding is heartening indeed when it is remembered that three-fourths of the Nation's traffic deaths now occur outside of urban areas. By contrast, heavy losses in property damage and nonfatal injury accidents are chiefly concentrated in urban and suburban areas. The safety merits of metropolitan area freeways are distinguished more by their markedly lower accident and injury rates, rather than by their improved fatality rates. Full control of access thus offers vital safety advantages for both rural and urban locations.

Full and Partial Access Control Compared

The hazards of incomplete treatment of the access problem are interestingly revealed by the accident records included in table 1 for facilities with only partial control. Fatality rates for sections having partial access control are highest on the urban and suburban sections studied, 5.6 and 5.5, respectively. Significant too is the fact that urban and suburban accident and injury rates are roughly double those found on comparable highways with fully planned access. On rural highway sections, the death rate with partial control is nearly twice that found on highways with full control of access.

Another facet of the study concerns the types of accidents that occur. The experience shows that on highways with full control of access, approximately 60 percent of the accidents involve rear-end collision or same-direction sideswipe. On routes with partial or no access control, the crashes in this category are roughly 40 percent of the total.

Rear-End Collisions, a Problem on Freeways

The higher percentage of rear-end or same-direction collisions on freeways is a matter for serious concern. Checking further, it is found that the rate for rear-end collisions on rural freeways is about 90 per 100 million vehicle-miles, which is substantially the same as that for rear-end collisions on other rural highways covered by the study. On urban freeways, however, rear-end collisions occur at an approximate rate of 130 per 100 million vehicle-miles, and at twice that rate on urban routes without access control. If the freeway has an Achilles heel, it is in its susceptibility, accidentwise, to driving actions that set up speed differentials, and rear-end collisions. In this connection, the points of entrance and departure are critical ones, and further design refinements will be needed on ingress and egress facilities.

Table 1.—Accident experience on highways in 27 States with full, partial, and no control of access [1]

Area and degree of access control	Length of study sections	Vehicle-miles of travel	Number of accidents	Number of fatalities	Number of injuries	Rates per 100 million vehicle-miles of travel		
						Accidents	Fatalities	Injuries
Urban:	*Miles*	*Thousands*						
Full control	75.6	1,318,848	2,556	29	1,169	194	2.2	89
Partial control	35.4	573,321	2,997	32	943	523	5.6	164
No control	119.4	1,813,534	9,092	74	4,739	501	4.1	261
Suburban:								
Full control	24.5	198,746	273	8	180	137	4.0	91
Partial control	99.1	613,374	2,253	34	961	367	5.5	157
No control	140.0	1,527,589	7,349	78	5,998	481	5.1	393
Rural:								
Full control	366.5	4,063,863	6,340	137	5,514	156	3.4	136
Partial control	579.0	2,396,668	5,002	151	3,536	209	6.3	148
No control	653.4	3,222,890	11,102	332	6,886	344	10.3	214
Totals:								
Full control	466.6	5,581,457	9,169	174	6,863	164	3.1	123
Partial control	713.5	3,583,363	10,252	217	5,440	286	6.1	152
No control	912.8	6,564,013	27,543	484	17,623	420	7.4	268
Grand total	2,092.9	15,728,833	46,964	875	29,926	298	5.6	190

[1] Data included are for various years, 1949–55, inclusive.

It is heartening to find that on highways with full control of access, fewer than 10 percent of the accidents involve head-on collision, angle collision, and collision with pedestrians. The corresponding values for highway sections with partial or no access control are much higher, ranging from about 35 to 50 percent. This difference is of much importance, for it involves those types of collisions that most frequently cause serious injury or death. The lower incidence of these severe collisions accounts in the main for the low fatality rate.

The world's most renowned highway design, the planned access freeway, clearly sets the scene for superior service to future traffic on the Interstate System. Now that additional mileages of interstate routes are being constructed and opened to traffic, it seems certain that the access control feature will persist as a prime value in highway safety.

Crash-Barrier Tests

(*Continued from page 252*)

nearly 20 feet greater. However, the hedge at the site of test No. 7 was far more dense and the bushes were larger when compared with those for test No. 12. The test car and hedge performance was very similar to that noted in the previous summer tests.

Acknowledgments

The author wishes to acknowledge the splendid cooperation received from personnel of the Bureau of Public Roads, the Connecticut State Highway Department, and the State Police of the Connecticut Motor Vehicle Department.

Special mention is due Dr. James A. Farnham, of South Windsor, Conn., for the donation of the hedge and use of his land.

Carl C. Saal, of the Bureau of Public Roads, deserves the personal thanks of the author for his assistance during the field tests, and for his careful review and help in preparing this report for publication.

Traffic and Travel Trends

(*Continued from page 265*)

in the Pacific division—78 vehicles in each 1,000 were overloaded to some extent and 2 vehicles in each 1,000 were overloaded by 20 percent or more. The second highest frequency was found in the East South Central division where 71 vehicles in each 1,000 were overloaded and 8 vehicles in each 1,000 were overloaded by 20 percent or more.

A comparison of frequencies of vehicles loaded in excess of the recommendations of the AASHO shows that the highest frequency of heavy loads likewise was in the Pacific division where 179 vehicles in each 1,000 exceeded the recommended weight limits, and 8 in each 1,000 exceeded these limits by 20 percent or more. The second highest frequency was found in the New England division where 117 vehicles in each 1,000 exceeded the recommendations and 56 in each 1,000 exceeded them by 20 percent or more. The high frequencies of loads exceeding the recommendations in the New England division, especially those exceeding the recommendations by 20 percent or more, are caused by the higher legal axle-load limits in effect in that area. Although the maximum axle-load limit recommended by the AASHO and permitted in most States is 18,000 pounds, the legal limit in States of the New England division ranges from 20,000 to 22,400 pounds. Consequently a considerable number of vehicles carrying loads within the State limits may exceed the recommendations of the AASHO by as much as 24 percent.

Motor-Vehicle Size and Weight Limits

A comparison of State legal limits of motor-vehicle sizes and weights with standards recommended by the American Association of State Highway Officials is given in a table on pages 256–257. The statutory limits reported in this tabulation, prepared by the Bureau of Public Roads as of July 1, 1957, have been reviewed for accuracy by the appropriate State officials.

Statutory limits are shown for width, height, and length of vehicles; number of towed units; maximum axle loads for single and tandem axles; and maximum gross weights for single-unit trucks, truck-tractor semitrailer combinations, and other combinations.

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STATUS OF FEDERAL-AID HIGHWAY PROGRAM

AS OF OCTOBER 31, 1957

(Thousand Dollars)

STATE	UNPROGRAMMED BALANCES	ACTIVE PROGRAM											
		PROGRAMMED ONLY			CONTRACTS ADVERTISED, CONSTRUCTION NOT STARTED			PROJECTS UNDER WAY			TOTAL		
		Total Cost	Federal Funds	Miles	Total Cost	Federal Funds	Miles	Total Cost	Federal Funds	Miles	Total Cost	Federal Funds	Miles
Alabama	$38,855	$68,811	$52,766	636.7	$18,218	$13,825	129.9	$72,420	$45,337	685.0	$159,449	$111,928	1,451.6
Arizona	19,792	32,654	28,851	188.1	6,640	5,075	56.8	26,036	22,572	179.5	65,330	56,498	424.4
Arkansas	49,536	27,587	19,360	466.3	15,987	10,958	129.5	48,686	32,525	449.3	92,260	62,843	1,045.1
California	147,690	20,937	14,704	136.3	24,278	17,825	24.8	410,330	216,479	357.2	455,545	249,008	518.3
Colorado	44,736	18,247	13,276	137.7	5,526	4,393	29.3	53,351	38,326	314.7	77,124	55,995	481.7
Connecticut	52,695	2,420	1,570	1.0	6,052	4,031	4.3	40,259	26,911	36.8	48,731	32,512	42.1
Delaware	31,131	2,740	1,398	21.8	2,519	1,233	16.7	13,282	7,680	55.3	18,541	10,311	93.8
Florida	58,220	37,719	25,873	420.0	17,563	13,200	41.6	43,861	25,532	257.6	99,143	64,605	719.2
Georgia	96,008	59,224	37,405	519.8	7,219	4,003	58.2	94,141	54,563	903.1	160,584	95,971	1,481.1
Idaho	41,466	17,946	14,270	105.8	7,463	5,277	43.0	15,921	11,039	144.5	41,330	30,586	293.3
Illinois	92,529	92,032	66,492	484.8	77,435	59,540	132.5	176,899	128,609	735.3	346,366	254,641	1,352.6
Indiana	142,271	27,682	14,946	214.7	16,616	8,599	202.6	51,310	32,212	268.7	95,608	55,757	686.0
Iowa	38,143	69,699	54,711	734.7	11,588	7,245	143.7	62,320	41,952	1,290.3	143,607	103,908	2,168.7
Kansas	49,133	43,082	35,191	786.6	8,178	5,270	101.0	47,056	30,369	1,136.5	98,316	70,830	2,024.1
Kentucky	62,019	38,206	28,385	118.2	7,006	4,153	32.4	57,802	39,535	262.0	103,014	72,073	412.6
Louisiana	67,836	44,233	27,974	267.2	13,291	8,483	75.4	53,266	29,357	338.5	110,790	65,814	681.1
Maine	41,504	7,599	5,247	24.4	1,386	765	7.4	19,132	10,433	115.1	28,117	16,445	146.9
Maryland	15,199	38,346	24,065	91.0	22,433	16,276	24.4	63,504	43,769	181.2	124,283	84,110	296.6
Massachusetts	55,513	50,737	38,077	33.3	52,879	33,115	36.6	66,777	40,623	46.5	170,393	111,815	116.4
Michigan	101,523	79,319	59,173	446.7	33,941	20,171	38.1	102,490	71,314	580.4	215,750	150,658	1,065.2
Minnesota	66,742	7,867	6,793	70.3	3,042	2,609	.5	112,728	82,292	1,534.1	123,637	91,694	1,604.9
Mississippi	20,426	52,048	39,245	700.7	23,790	19,772	100.0	58.008	38,341	850.8	133,846	97,358	1,651.5
Missouri	75,072	4,912	28,931	999.9	12,471	9,903	16.8	116,461	74,964	1,250.3	173,844	113,798	2,267.0
Montana	66,609	14,111	10,161	267.4	4,747	3,122	33.9	41,090	30,602	250.5	59,948	43,885	551.8
Nebraska	78,848	11,164	5,914	213.2	9,881	5,740	83.2	40,762	24,091	1,156.7	61,807	35,745	1,453.1
Nevada	32,677	13,416	12,596	29.0				27,461	24,847	130.0	40,877	37,443	159.0
New Hampshire	19,473	9,333	7,213	21.8	2,443	1,770	4.7	21,402	14,264	62.6	33,178	23,247	89.1
New Jersey	102,670	10,119	5,563	71.6	6,808	3,655	2.0	75,327	53,085	57.6	92,254	62,303	131.2
New Mexico	29,802	7,009	4,280	76.2	9,995	7,737	71.8	36,240	30,019	252.6	53,244	42,036	400.6
New York	168,564	35,253	22,116	92.9	105,067	75,798	75.1	488,605	293,652	495.4	628,925	391,566	663.4
North Carolina	103,900	25,093	16,313	213.3	10,327	7,516	36.0	81,423	50,466	875.0	116,843	74,295	1,124.3
North Dakota	39,688	19,091	13,947	860.0	5,236	4,211	59.4	22,229	14,377	997.3	46,556	32,535	1,916.7
Ohio	40,378	148,724	107,298	249.9	31,760	25,597	33.1	210,861	142,345	303.4	391,345	275,240	586.4
Oklahoma	46,255	56,280	41,739	499.6	12,988	9,304	68.0	61,134	37,861	569.5	130,402	88,904	1,137.1
Oregon	41,126	8,381	6,518	28.2	8,928	6,863	35.0	43,904	33,554	213.9	61,213	46,935	277.1
Pennsylvania	156,705	86,462	55,661	200.9	49,304	37,122	73.8	234,675	150,298	372.8	370,441	243,081	647.5
Rhode Island	17,606	4,584	2,405	6.4	3,320	2,848	1.6	37,747	25,223	23.9	45,651	30,476	31.9
South Carolina	49,869	43,557	30,684	454.3	3,051	2,463	17.5	38,053	22,256	746.3	84,661	55,403	1,218.1
South Dakota	40,979	27,554	21,668	341.9	553	310	24.4	22,324	15,783	492.7	50,431	37,761	859.0
Tennessee	55,555	68,291	51,612	354.6	14,597	9,157	22.5	84,662	51,280	520.8	167,550	112,049	897.9
Texas	210,119	18,159	9,909	446,7	66,230	51,872	210.2	173,399	116,175	1,553.6	257,788	177,956	2,210.5
Utah	9,110	38,527	34,800	220.8	4,177	3,117	26.2	23,900	19,668	105.8	66,604	57,585	352.8
Vermont	23,526	3,941	2,143	32.0	47	23	.2	20,464	15,219	39.8	24,452	17,385	72.0
Virginia	29,416	67,139	54,626	134.6	22,530	16,974	46.4	62,033	41,149	263,7	151,702	112,749	444.7
Washington	58,094	21,148	15,686	113.6	4,528	3,850	41.8	54,527	39,123	253.6	80,203	58,659	409.0
West Virginia	42,389	45,913	34,177	82.1	4,801	2,425	11.4	38,853	21,375	84.6	89,567	57,977	178.1
Wisconsin	102,601	17,835	10,838	272.8	11,368	8,377	87.1	57,717	35,552	394.9	86,920	54,767	754.8
Wyoming	5,460	25,853	21,071	178.7	4,102	2,825	23.3	49,491	40,843	330.5	79,446	64,739	532.5
Hawaii	5,858	8,583	4,291	13.4	1,272	631	3.6	2,677	1,256	1.3	12,532	6,178	18.3
District of Columbia	29,395	7,290	5,274	3.3	4,649	3,174	2.9	17,598	14,197	3.2	29,537	22,645	9.4
Puerto Rico	13,985	9,160	4,100	7.9				18,991	9,005	57.0	28,151	13,105	64.9
Alaska	13,570	4,130	4,130	58.8	1,087	1,087	23.2	10,594	9,087	335.0	15,811	14,304	417.0
TOTAL	3,042,266	1,740,147	1,255,436	13,151.9	799,317	573,289	2,563.8	3,904,183	2,521,386	22,916.7	6,443,647	4,350,111	38,632.4